Industrial QUALITY CONTROL

Vol. XII, No. 9
MARCH, 1956

" . . . . . and now remains

That we find out the cause of this effect,

Or rather say, the cause of this defect,

For this effect defective comes by cause;"

Hamlet: Act II, Scene 2

1906—TENTH ANNIVERSARY YEAR—1956

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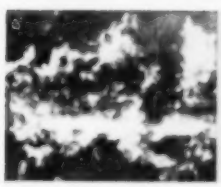

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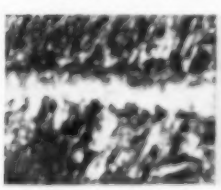

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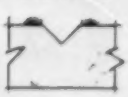
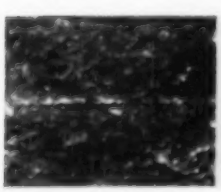


Here again mica soon causes a poor surface finish.



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Quality Control

Vol. XII, No. 9 March, 1956

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Industrial Quality Control is published monthly by the American Society for Quality Control, Inc. Entered as second-class matter on Sept. 18, 1950, at the post office at Milwaukee, Wis.

Executive secretary's office: Room 563, 50 Church St., New York 7, N. Y. Publications office: Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis. Advertising Representatives: Weston and Weston, 6 East 39th Street, New York, N. Y.

IQC is sent to all members of the Society as one of the privileges of membership; yearly subscription is $3.00 of the membership dues. Subscriptions from non-members are not accepted. Subscriptions for company, public and university libraries are: 1 yr.—$9.00; 2 yrs.—$17.00; 3 yrs.—$25.00; 5 yrs.—$40.00.

Back issues of Vols. I-X are available at $6.00 per volume including index. Back issues of Vol. XI are $9.00. Individual copies are $1.00 each. Orders for library subscriptions and back issues should be accompanied by remittance in United States funds made payable to the American Society for Quality Control, Inc. and sent directly to the executive secretary's office.

Notification of address change should be sent both to the secretary of your section and to the executive secretary's office. Allow approximately seven weeks for the change to become effective.

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Practical Linear Programming Applications

HARRY T. SCHWAN

Methods Engineering Council, Pittsburgh, Pa.

One of the brightest spots on management's horizon today is a new tool called **Linear Programming**. This new tool is already helping management to make better decisions on some of its most complicated problems. If the applications that have already been made are an indication of its usefulness, then it is likely to be one of the most valuable aids to management decision-making which has turned up in the past fifty years.

Linear programming is useful because it adds precision to the process of decision-making. It permits management to move along a positive course of action knowing that that course of action is the best it can do under its own present circumstances. It provides management with facts which are predicated upon a consideration of the total problem rather than piecemeal consideration of various parts of the problem.

Areas of Application

Linear programming has already been applied with excellent and even spectacular results to determine:

- the most profitable manufacturing program
- the best inventory strategies
- the effect of changes in purchasing and selling price
- whether to make or buy certain component parts
- the most profitable product mix
- the best location of plants
- the best location of warehouses and distribution outlets
- the lowest cost machine or manufacturing schedule.

This is only a partial list of applications, but it does point out the type of problem upon which linear programming is most useful. Notice that there are some common characteristics in each one of these problems.

First, to make a decision on any one of these problems the manager must consider a very large number of factors. Second, these factors are almost always inter-dependent so that the manager must consider them both individually and in relation to each other. And, third, the manager is faced with having to choose *one* solution or course of action from among several obvious courses of action and, perhaps, several others which are not so obvious.

It surely would take an unbelievably brilliant human mind to understand, weigh, balance, and keep in their proper perspective all of these factors, and to pick the best solution. In the past, most of us who have had to face these situations have done a lot of decision-making based on experience, feel, intuition, hope, and pure "guesstimate." We have had to do this because we had no other tool that could add precision to our deliberations. The best human minds have not been capable of accommodating, with precision, problems which are this complicated.

How Linear Programming Assists Management

Linear programming, from the manager's point of view, is both an *approach* to the formulation and statement of these complicated problems and a set of *mathematical procedures* that enables him to handle the complications and select the best course of action. Stated another way, linear programming helps the manager to:

- *organize* the facts and information about a problem
- *analyze* all possible alternative solutions to the problem
- *select* the best course to follow under his own conditions and limitations
- *plan* the specific steps required to get the best results
- *re-evaluate* the plan when conditions change.

Let's consider each of these points for a moment.

We have found that, when we go to *organize* a problem so that it can be handled by the linear programming mathematical procedures, we nearly always gain a new perspective and keener insight into the problem. In some cases this *added clarity* has given us a *different and more valuable picture* of the *true problem*. It has led us more surely to *causes* rather than *effects*. To permanent solutions rather than stop-gap expedients.

We want to analyze all reasonable courses of action, because, for various reasons, we may not choose to follow the *best* course of action. With linear programming we can readily determine what we are giving up by following a course of action other than the best one.

Linear programming identifies the best course of action for us to follow under the conditions which affect us. We can build into our solution a true reflection of our own limitations or restrictions in marketing, production facilities, finance,

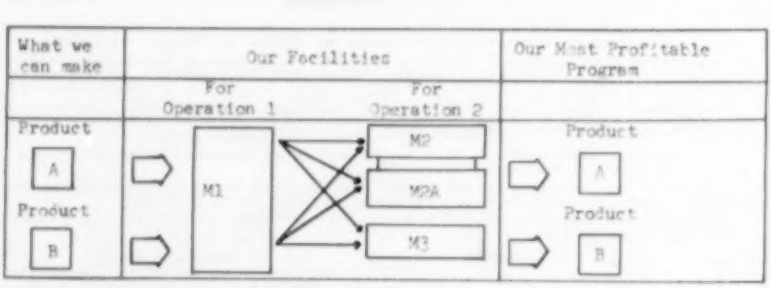

Figure 1—A Typical Production Planning Problem

manpower, and many other practical operating factors.

The solution we obtain comes out in specific, quantitative terms—how many shall we make—how shall we make them—where shall we make them. With this type of information we can plan the specific actions we will need to take to get the results that are possible.

Finally, and this is exceedingly important, we can *re-evaluate* our plans and programs when conditions change or when we think they might change. This means we have a before-the-fact tool as well as an after-the-fact tool. It means that we have a tool that is practical in the ever-moving, ever-changing, business atmosphere in which we must make decisions.

Linear Programming in Action

The best way to get an idea of the way linear programming works is to follow through a typical problem. This problem illustrates how linear programming can be helpful in planning for maximum profits. Figure 1 illustrates the situation that confronts us.

We have a plant that is capable of making two products, A and B. To make these products we have available certain facilities. The nature of the products is such that two operations are required on each, but the first operation must be performed on Machine Group 1. In Fig. 1 this Machine Group is designated M1. For operation 2, however, we have three choices as to where it can be performed for either product. We can use Machine Group 2 (M2 in Fig. 1) on straight time, Machine Group 2 on overtime (M2A in Fig. 1), or we can use Machine Group 3 (M3 in Fig. 1.)

Considering what we can make and what we have to make it with, our management has asked us what manufacturing program will provide the most profitable use of these facilities. They want us to tell them how many of each product to make, which of the three manufacturing alternatives to use, and how much profit this program will produce.

TABLE II—Most Profitable Production Program as Determined Through Linear Programming

Production Quantities		Facilities Used	Profit
Product A	Product B		
200,000		M1 & M2	$170,000
66,667		M1 & M2A	40,000
200,000		M1 & M3	140,000
466,667 Total	None		$350,000 Total

Machine	Hours Needed			Total Hrs. Needed	Hours Avail.	W
M1	400	133.3	400	933.3	1000	0
M2	600			600	600	283
M2A		200		200	200	200
M3			800	800	800	175

Before we can determine our best course of action, we need the additional information given in Table I.

Naturally, there must be a limitation on how much time can be spent to produce our two products. These time limitations are given in the right-hand column. We have 1000 hours available on M1, 600 hours available on M2, 200 hours of overtime available on M2A, and 800 hours available on M3.

The data in the center of the chart show the time in hours to manufacture 1000 pieces for each operation, on each product, and by each manufacturing alternative.

On the bottom line we see some very important figures which give us the unit profit for each product when it is manufactured by each manufacturing alternative.

Before we look at the answer to this problem, let's remember that our management has asked us for the most profitable *manufacturing* program, and that no restriction has been placed on our ability to sell whatever we decide to turn out. We will build in the sales restriction later.

The result of applying linear programming to this problem is given in Table II.

The largest possible profit is obtained when all machines are used to make Product A. A lower profit will be made if any of Product B is produced despite the fact that the profit per piece on Product B is much higher than on A. As Table II indicates, the program which should be followed is:

- use M1 and M2 to make 200,000 pieces of Product A which will give $170,000 profit
- use M1 and M2A (M2 on overtime) to make 66,667 pieces of Product A which will give $40,000 profit
- use M1 and M3 to make 200,000 pieces of Product A which will give $140,000 profit
- the maximum profit is, therefore, $350,000.

The time required of each machine group to follow this program is also given in Table II.

The first interesting thing to note from the table is that we should use less than the total capacity of M1 in order to obtain maximum profit. If we fall into the trap of using all of M1's 1000 hours, we will lower our profit—we simply succeed in building up work-in-process inventory.

Next, look at the W column. The $283 figure opposite M2 means that we can increase our profit by $283 for each hour of additional capacity we can provide on M2. It is particularly interesting to note that we can make more profit from an extra hour of overtime on M2 than from an extra hour of straight time on M3. These figures hold, of course, only until we have used all of the capacity available on M1.

Thus we have definite and specific answers as to what to do and how to do it for maximum profits. The total time figures provide a basis for planning manpower and maintenance activities. The unit quantity and time figures provide firm figures upon which to base purchasing, inventory, and sales plans. We can use these figures knowing that we have looked at our *total* problem and that all of our planning and action will be coordinated and aimed at maximum profit.

TABLE I—Manufacturing Information on the Facilities Given in Fig. 1

Operation	Mach. Group	Hours per 1000 Pieces						Hours Available
		Product A			Product B			
1	M1	2	2	2	5	5	5	1000
2	M2	3			8			600
2	M2A		3			8		200
2	M3			4			10	800
Profit/piece		.85	.60	.70	1.60	1.40	1.30	

TABLE III—Most Profitable Program if You Must Make 100,000 Units of Product B

Product	Manufacturing Alternative			Total Production
	M1-M2	M1-M2A	M1-M3	
A	200,000	0	12,500	212,500
B	0	25,000	75,500	100,000

Maximum Profit = $311,250
Sacrifice Profit = $ 38,750
Sacrifice Production = 254,167 units of A

TABLE IV—Most Profitable if Unit Profit Drops Nine Cents on Product A

Product	Manufacturing Alternative			Total Production
	M1-M2	M1-M2A	M1-M3	
A	200,000	0	200,000	400,000
B	0	25,000	0	25,000

Maximum Profit = $309,000
Sacrifice Profit = $ 41,000
Sacrifice Production = 66,667 units of A

TABLE V—Production Capacities and Customer Demands Involved in the Problem of Fig. 2

Plant	Location	Capacity per Month
1	Chicago	5,000 units
2	Boston	3,000 units
3	Atlanta	10,000 units

Warehouse	Location	Monthly Customer Demand
W1	Cincinnati	1,000 units
W2	New York	4,000 units
W3	Toronto	6,000 units
W4	Baltimore	2,000 units
W5	Knoxville	2,000 units
W6	Pittsburgh	3,000 units

The Effect of Introducing Added Restrictions

Let us look, now, at what our program might be with an additional restriction. Suppose that 100,000 pieces of Product B have been sold and must be produced. All other conditions remain the same. The most profitable production program becomes that shown in Table III.

We see that our facilities are now used in a different way. Most of Product A is produced on Machine Group M1 in conjunction with M2. Only a small amount is produced on Machine Group M3, and M2A is not used at all. Three quarters of the production of Product B is obtained from using a combination of Machine Groups M1 and M3 with the balance coming from M1 and M2A.

The profit for this program is $311,250. By comparing this to the original profit of $350,000, we see that by producing 100,000 pieces of B, $38,750 of profit are foregone. In addition, the number of Product A that will be available for delivery is reduced by 254,167.

The questions now raised are:

"Are the customers to whom these 100,000 units of B were committed worth a sacrifice of $38,750 in profit," and

"If we give up 254,167 pieces of A, can we meet our sales requirements for that product."

Linear programming will not make a decision for us in this situation, but it will certainly place in our hands a means of evaluating the consequences of our decision.

Forecasting The Effect of a Change in Selling Price

Now, how is linear programming used as a before-the-fact tool? Assume that we are progressing along the original program making none of Product B. Our sales manager forecasts that in order to stay competitive on Product A we will have to reduce our selling price to the extent that the profit per piece on Product A drops by nine cents. What should we do? Table IV gives the answer as developed by linear programming.

It now becomes profitable to manufacture 25,000 units of Product B. This program yields a profit of $309,000. Our profit potential drops by $41,000 and we give up 66,667 units of Product A. Had the original program been continued (466,667 pieces of A, 0 pieces of B), the profit would have amounted to $308,000 using the lower profit per piece. In this case we might decide to continue with the original program for reasons other than greatest profit since the difference between the two programs is so small. The advantage of going through the process of determining the most profitable program is that it provides the means for determining what the cost is in terms of lost opportunity. For example, further reductions in the selling price of Product A will very soon make it more profitable to manufacture Product B—a point which may not be quickly determined otherwise.

The item of greatest importance in basing decisions upon linear programming is that we are always looking at our entire problem rather than part of it. Our decision is made on the basis of factual information and in terms of over-all company profits.

A Problem Involving Distribution Costs

Not all of management's problems are as broad as the one we've just discussed. For instance, scheduling in a machine shop can be done considering only one department by itself. The following problem, illustrated by Fig. 2, uses linear programming in a narrower sense to reduce an important item of distribution costs.

The company in question manufactures its products in three plants, P1, P2, and P3. It distributes its product through six warehouses, W1 through W6. The president of this

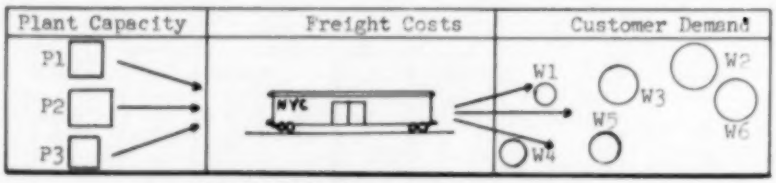

Figure 2—A Distribution Cost Reduction Problem

company is faced with reducing distribution costs but he knows that today, at least, he cannot do anything that might interfere with on-time deliveries to customers. He has stated, therefore, that he wants to obtain the lowest possible freight costs and still keep his plant capacity and customer needs in balance. Tables V and VI present the information we need if we are to answer this problem.

Table V shows that the company's three plants are located in Chicago, Boston, and Atlanta and that their respective productive capacities are 5,000, 3,000, and 10,000 units per month.

Similarly, Table V presents the locations of the company's six warehouses and records the number of units per month needed by each for distribution to retailers. Cincinnati, for example, requires 1000 units per month to satisfy customer needs.

Table VI shows the freight costs for shipping one unit from each of the company's three plants to each of the six warehouses.

TABLE VI—Schedule of Unit Freight Costs

Plant	Warehouse					
	W1	W2	W3	W4	W5	W6
P1	3	3	2	5	2	1
P2	4	1	1	2	2	1
P3	2	2	5	1	1	2

The cost of shipping one unit between Plant 1 in Chicago and Warehouse 3 in Toronto, for instance, is two dollars.

A Solution Based on Lowest Freight Cost

Before solving this problem by linear programming, let's see what would happen if we decided to make all shipments on the basis of lowest freight cost. Table VII presents the shipping schedule that would result.

This shipping schedule gives us a total freight cost of $19,000. BUT, can we meet our delivery schedule? Obviously we can't because, as the figure shows, P2 would be called upon to produce over three times its capacity.

A Logical Solution

Now let's set up another shipping schedule that stays in line with plant capacity and at the same time provides for the meeting of customer needs.

The typical way of doing this is to start with the requirements of Warehouse 1 and obtain them from the source that results in lowest freight charges. Then we would proceed to Warehouses 2, 3, and so on considering both the remaining plant capacities and freight costs. Table VIII presents the results of following this logical approach to a solution.

One question of major importance remains unanswered, however. Can we set up a better solution and thus reduce our freight costs below the $39,000 shown in Table VIII?

TABLE VII—Shipments Based Only on Lowest Freight Cost.

Plant	Plant Capacity	Units Shipped To						Total Shipments	% of Cap. Used
		W1	W2	W3	W4	W5	W6		
P1	5,000						3000	3,000	60
P2	3,000		4000	6000				10,000	330
P3	10,000	1000			2000	2000		5,000	50
		Total Freight Cost = $19,000							

TABLE VIII—A Solution Arrived at by Logic (The Typical Procedure)

Plant	Plant Capacity	Units Shipped To						Total Shipments
		W1	W2	W3	W4	W5	W6	
P1	5,000		4000	1000				5,000
P2	3,000			3000				3,000
P3	10,000	1000		2000	2000	2000	3000	10,000
		Total Freight Cost = $39,000						

TABLE IX—The Best Solution (Arrived at Through Linear Programming)

Plant	Plant Capacity	Units Shipped To						Total Shipments
		W1	W2	W3	W4	W5	W6	
P1	5,000			3000			2000	5,000
P2	3,000			3000				3,000
P3	10,000	1000	4000		2000	2000	1000	10,000
		Total Freight Cost = $27,000						

The Linear Programming Best Solution

With linear programming, we can readily determine whether or not we can do better. And more important, we can determine a definite and specific shipping schedule which we will know is the best we can do.

Table IX shows the best shipping schedule that results from applying linear programming.

We know now that under the specified conditions and limitations we cannot lower freight costs under $27,000. In adition we know how many units should be shipped from each plant to each warehouse in order to realize this cost.

With linear programming we end up with the best solution under the circumstances and limitations faced. We can tell when we have arrived at the best solution. If we decide to follow something other than the best plan, we can measure the cost of this decision. Furthermore, the answer is, again, in terms of a definite and specific course of action. In this problem, for instance, we know exactly how many units to ship from each plant to each warehouse and we know that the best we can do in freight costs is $27,000.

One of the most interesting and useful applications of linear programming is a reverse application of this shipping schedule example. By doing this in reverse, it is a relatively simple problem to determine the best location of distribution or warehousing points for a given product or combination of products.

These two examples are hardly more than a hint of the wide range of management problems upon which linear programming can be helpful. There is, of course, no lessening of the need for good management judgment, but that judgment can now be supported with vastly expanded insight into the complications surrounding each decision. Managers can look forward to much less "guesstimate" and "seat-of-the-pants operation" in their work, and much more fact and precision in their approach to the difficult problems ahead. We are, indeed, coming

closer each day to the time when management will be less of an art and more of a science.

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Linear Programming

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Linear programming deals with maximizing or minimizing a linear function of several real variables subject usually to the requirement that the variables be nonnegative and satisfy certain additional linear inequalities (or equations.) The following problem is an illustration, in miniature.

Example 1

To *maximize* $2x + 5y$ subject to the five constraints

$$x \geq 0,\ y \geq 0$$
$$x \leq 4,\ x + 2y \leq 8,\ y \leq 3$$

This problem can easily be solved graphically since just two variables occur in it. The set of *feasible* points (x, y) satisfying all five constraints is a pentagonal region bounded by the y-axis ($x = 0$), the x-axis ($y = 0$), and the lines $x = 4$, $x + 2y = 8$, $y = 3$, as shown in Fig. 1. The function $2x + 5y$, which is to be maximized, is represented by contour lines (broken) along which it takes the values 5, 10, 15, 20, as indicated. We see that the desired maximum seems to occur at the corner determined by the intersection of the two constraint lines

$$x + 2y = 8,\ y = 3$$

namely, at the point $x = 2$, $y = 3$, for which

$$2x + 5y = 19$$

In order that this be the desired maximum it is necessary that the contour line $2x + 5y = 19$ should not enter into the interior of the pentagonal region of feasible points. (Figure 2.) Hence the vector $(2, 5)$ normal to the contour line $2x + 5y = 19$ must belong to the "angle" spanned by the vectors $(1, 2)$ and $(0, 1)$ normal to the constraint lines $x + 2y = 8$ and $y = 3$, respectively. That is, there must exist nonnegative coefficients v and w such that

$$(2, 5) = v(1, 2) + w(0, 1)$$

which requires

$$v = 2,\ 2v + w = 5$$

The nonnegative solution $v = 2$, $w = 1$ of this pair of auxiliary equations yields the breakdown

$$2x + 5y - 19 = 2(x + 2y - 8) + (y - 3)$$

Hence $2x + 5y \leq 19$ for all (x, y) such that $x + 2y \leq 8$, $y \leq 3$. This provides an algebraic check that the feasible point $x = 2$, $y = 3$ gives $2x + 5y$ its maximum value 19 subject to the five stated constraints.

Example 2

To *minimize* $4u + 8v + 3w$ subject to the five constraints

$$u + v \geq 2,\ 2v + w \geq 5,$$
$$u \geq 0,\ v \geq 0,\ w \geq 0$$

Here the set of feasible points (u, v, w) satisfying all five constraints is a pentahedral region bounded by the planes $u = 0$, $v = 0$, $w = 0$, $u + v = 2$, $2v + w = 5$. It consists of the positive octant ($u \geq 0$, $v \geq 0$, $w \geq 0$) with two prisms removed, the one bounded by the three planes $u + v = 2$, $u = 0$, $v = 0$ and the other by the three planes $2v + w = 5$, $v = 0$, $w = 0$. It possesses three corner, or extreme, points:

$(0, 2, 1)$, the intersection of $u + v = 2$, $2v + w = 5$, $u = 0$,

$(2, 0, 5)$, the intersection of $u + v = 2$, $2v + w = 5$, $v = 0$,

$(0, 2.5, 0)$ the intersection of $2v + w = 5$, $u = 0$, $w = 0$.

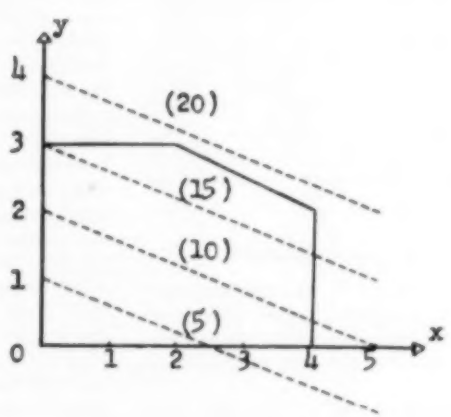

Figure 1

At these three extreme feasible points the function $4u + 8v + 3w$, which is to be minimized, takes the values 19, 23, 20, respectively. To make sure that the point (0, 2, 1) minimizes $4u + 8v + 3w$ subject to the five constraints, it is necessary to express the vector (4, 8, 3) normal to the contour plane $4u + 8v + 3w = 19$ as a nonnegative linear combination of the vectors (1, 1, 0), (0, 2, 1), (1, 0, 0) normal to the constraint planes $u + v = 2$, $2v + w = 5$, $u = 0$, respectively:

$$(4, 8, 3) = x(1, 1, 0) + y(0, 2, 1) + z(1, 0, 0)$$

That is, it is necessary to solve

$$x \geq 0,\ y \geq 0,\ z \geq 0,$$
$$x + z = 4,\ x + 2y = 8,\ y = 3$$

or, setting $z = 4 - x$, to solve

$$x \geq 0,\ y \geq 0,$$
$$x \leq 4,\ x + 2y = 8,\ y = 3$$

The solution $x = 2$, $y = 3$, with $z = 2$, yields the breakdown

$$4u+8v+3w-19 = 2(u+v-2) + 3(2v+w-5) + 2u$$

Hence $4u + 8v + 3w \geq 19$ for all (u, v, w) such that $u + v \geq 2$, $2v + w \geq 5$, $u \geq 0$. This provides an algebraic check that the feasible point (0, 2, 1) gives $4u + 8v + 3w$ its minimum value 19 subject to the five stated constraints.

Interrelation of 1 and 2

By now it should be evident that Examples 1 and 2 are closely related. They involve the same data and have a common optimum value, 19. Moreover, a check of the solution of either one rests on a breakdown in terms of the solution of the other. The common structure of the two problems is exhibited conveniently by the following scheme of "detached coefficients."

(≥ 0)	x	y	(≤)
u	1	0	4
v	1	2	8
w	0	1	3
(≥)	2	5	

Example 1 pertains to the inner (dot or scalar) products of *rows* in this scheme with the initial row (x, y); we seek a point or vector (x, y) that maximizes the inner product of (2, 5) with (x, y), namely $2x + 5y$, subject to the individual components of (x, y) being nonnegative and to the inner products of the rows (1, 0), (1, 2) and (0, 1) with (x, y) not exceeding 4, 8 and 3, respectively. Example 2 pertains to inner products of *columns* in the scheme with the initial column (u, v, w); we seek a point or vector (u, v, w) that minimizes the inner product of (4, 8, 3) with (u, v, w), namely $4u + 8v + 3w$, subject to the inner products of the columns (1, 1, 0) and (0, 2, 1) with (u, v, w) being not less than 2 and 5, respectively, and to the individual components of (u, v, w) being nonnegative.

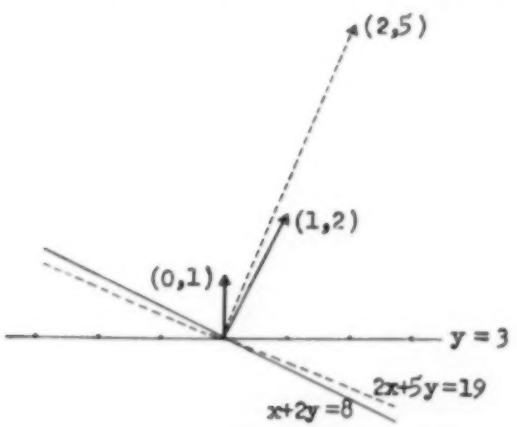

Figure 2

The solutions already obtained can be readily checked by substituting in the scheme.

(≥ 0)	2	3	(≤)
0	1	0	4
2	1	2	8
1	0	1	3
(≥)	2	5	19

The final step is to test the two solutions against one another by forming the inner product of (2, 5) with (2, 3) and of (4, 8, 3) with (0, 2, 1). Both inner products are 19, the common maximum and minimum. This completes the check.

General Dual Linear Programming Problems

A general pair of *dual* linear programming problems is presented by a similar matrix scheme.

(≥ 0)	x_1	x_2	...	x_n	(≤)
u_1	a_{11}	a_{12}	...	a_{1n}	b_1
u_2	a_{21}	a_{22}	...	a_{2n}	b_2
.	.	.		.	.
.	.	.		.	.
.	.	.		.	.
u_m	a_{m1}	a_{m2}	...	a_{mn}	b_m
(≥)	c_1	c_2	...	c_n	

Here the "row" problem is to find a vector $X = (x_1, x_2, \ldots, x_n)$ that *maximizes* the inner product

$$C \cdot X = c_1x_1 + c_2x_2 + \ldots + c_nx_n$$

subject to the m row constraints

$$a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n \leq b_i \quad (i=1,2,\ldots,m) \qquad (1)$$

and the n nonnegative constraints on the individual components of X

$$x_j \geq 0 \qquad (j=1,2,\ldots,n) \quad (2)$$

The "column" problem is to find a vector $U = (u_1, u_2, \ldots, u_m)$ that *minimizes* the inner product

$$B \cdot U = b_1u_1 + b_2u_2 + \ldots + b_mu_m$$

subject to the n column constraints

$$a_{1j}u_1 + a_{2j}u_2 + \ldots + a_{mj}u_m \geq c_j \quad (j=1,2,\ldots,n) \quad (3)$$

and the m nonnegative constraints on the individual components of U

$$u_i \geq 0 \qquad (i=1,2,\ldots,m) \quad (4)$$

A vector X or U that satisfies the m + n constraints (1) and (2) or (3) and (4) is called *feasible*. The test

whether a feasible X or U yields the desired maximum or minimum is provided by the following "fundamental theorem."

THEOREM 1. A feasible X or U is a solution of the stated maximum ("row") or minimum ("column") problem if, and only if, there exits a feasible U or X such that $B \cdot U = C \cdot X$.

Since the roles of the solution vector X or U and the "test" vector U or X in this Theorem are interchangeable, it is seen that the "test" vector is actually a solution for the minimum or maximum problem, respectively. That is, either both problems possess solutions or neither possesses a solution. The condition for solutions to exist is stated in the following theorem.

THEOREM 2. Solutions X and U exist if the two dual problems are both feasible, i.e. if both possess feasible vectors.

Proofs of these theorems rest on a basic theorem of J. Farkas* which states that a homogeneous linear inequality (written ≥ 0) is a nonnegative linear combination of a system of such inequalities (all written ≥ 0) if it is satisfied by all solutions of the system.†

Example of the General Problem

As an application of linear programming consider the following *Activity Analysis* problem [1]. Let there be n ways ("activities") of making a single desired commodity from available stocks of m primary commodities ("materials"). Let

$$a_{ij},\ b_i,\ c_j,\ \text{and}\ x_j$$

be, respectively, (a) the amount of the ith material used in one unit of the jth activity, (b) the available stock of the ith material, (c) the quantity of the desired commodity made by one unit of the jth activity, and (x) the number of units of the jth activity to be undertaken. Then, assuming "constant returns to scale," the problem is to find an "activity vector" $X = (x_1, x_2, \ldots, x_n)$ that will *maximize* the total output

$$C \cdot X = c_1x_1 + c_2x_2 + \ldots + c_nx_n$$

subject to the m constraints (1), above, set by the available stocks of the m materials and to the n constraints (2), above, set by the natural impossibility of negative "activity levels."

	activity levels		
(≥ 0)	$x_1 \ \ldots\ x_n$		$(\leq)$
u_1	$a_{11} \ \ldots\ a_{1n}$		b_1
accounting prices of materials	materials used per activity unit		available stocks of materials
u_m	$a_{m1} \ \ldots\ a_{mn}$		b_m
$(\geq)$	$c_1 \ \ldots\ c_n$		
	outputs per activity unit		

The *dual* problem pertains to accounting (fictitious or "shadow") prices attached to the m materials, on a scale whose unit is the price of the desired commodity. One seeks a "price vector" $U=(u_1,u_2,\ldots,u_m)$ that *minimizes* the total accounting value

$$B \cdot U = b_1u_1 + b_2u_2 + \ldots + b_mu_m$$

of the available stocks of materials subject to the"one-can't-get-something-for-nothing" requirement (3) that the total accounting value of the materials used in one unit of each activity is not less than the accounting value of the quantity of the desired commodity produced by one unit of that activity, and the requirement (4) that the accounting prices be nonnegative.

The traditional calculus procedure for finding a constrained maximum or minimum employs *Lagrange multipliers.* These may be adapted to our linear programming problems by introducing the Lagrangian function

$$\begin{aligned}\phi(X,U) &= c_1x_1 + \ldots + c_nx_n + u_1\,(b_1 - \Sigma\, a_{1j}x_j) \\ &\quad + \ldots + u_m\,(b_m - \Sigma\, a_{mj}x_j) \\ &= b_1u_1 + \ldots + b_mu_m + x_1\,(c_1 - \Sigma\, a_{i1}u_i) \\ &\quad + \ldots + x_n\,(c_n - \Sigma\, a_{in}u_i).\end{aligned}$$

In the first expression on the right the u's are Lagrange multipliers applied to the maximum ("row") problem while in the second the x's are Lagrange multipliers applied to the minimum ("column") problem. This bilinear symmetry is very gratifying but, of course, just reflects the fundamental duality already observed.

THEOREM 3. X and U are solutions of the maximum ("row") and minimum ("column") problems if, and only if, they determine a "saddle-point" at which the Lagrangian function $\phi(X, U)$ *has a* **minimax** *value, minimum as regards all nonnegative U and maximum as regards all nonnegative X.*

This theorem is closely related to Theorem 1.* In the activity analysis problem, $\phi(X, U)$ is the combined accounting value of the total output $C \cdot X$ of the desired commodity and of the unused balances of the materials.

The computation of solutions of linear programming involving a large number of variables has been and continues to be an important research task of the Department of the Air Force and of the National Bureau of Standards (see Ref. [2].) Dr. G. B. Dantzig, an outstanding pioneer in the field, has devised an ingenious "simplex method" of solving linear programming problems or general systems of linear inequalities and equations, analogous to the Gauss elimination method for solving systems of linear equations (see Ref. [1], pp. 339-373). It is generally true, as Examples 1 and 2 indicated, that the corner or extreme solutions of linear programming problems are just the solutions of a subsystem of linear equations obtained from the subset of constraints that determine the corner or extreme feasible point. But, with a large number of variables, it becomes a very complex matter of trial and error to isolate the constraints that determine a corner or extreme solution.

Reference [3] provides an excellent introduction to linear programming, its methods and varied applications, growing out of work done at the Carnegie Institute of Technology for the Department of the Air Force.

*Journal für die reine und angewandte Mathematik, 124 (1902) pp. 5-7

†For details see the paper on "Linear programming and the theory of games" by D. Gale, H. W. Kuhn, and A. W. Tucker, pp. 317-329 in Reference [1]

*A proof of a more general minimax theorem has been given by H. W. Kuhn and A. W. Tucker in "Nonlinear Programming." Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability (University of California Press, 1952) pp. 481-492.

Acknowledgment

This report is based on work done for the Logistics Project, Princeton University, and the Logistics Research Project, The George Washington University, under contracts with the Office of Naval Research.

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The Use of Linear Programming to Improve the Quality of Decisions

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Ways of Improving Decisions

There are several ways of improving the quality of decisions: by a more careful analysis of the problem, by taking into consideration a larger number of relevant factors, by the collection of better data, by the better interpretation of the data, and by making a decision at the most appropriate time. It is now well recognized that probability sampling and statistical quality control contribute to the improvement of decisions because they often result in better data, in a better interpretation of the results, and in a more timely use of the data for purposes of planning and action.

A new technique for improving decisions has now been added, that of linear programming. It contributes to quality of decisions because it allows the specialist or administrator to take into consideration a wide variety of factors and variables which are difficult if not impossible to allow for on an intuitive or experiential basis. It provides information for planning and policy making not now available to management. However, it is not a panacea; it does not replace judgment. What it does provide is a sounder basis on which many judgments can be based.

What is Linear Programming?

Linear programming is a technique which has been developed during the past decade for the purpose of solving certain kinds of problems encountered in business and government. It has been applied to activity and allocation analysis, to such problems as minimizing shipping costs, locating warehouses, and blending gasolines. A review of the literature thus far available indicates that it can be applied to immediate operating problems as well as to operations research and to top-level planning, although the emphasis seems to be on the latter rather than on the former.

Linear programming makes it possible to solve certain complex problems of management where it is necessary to impose several administrative and technical restrictions on the solution of the problem, and where it is desired to maximize or to minimize some significant characteristic of the situation, such as profit or cost.

In a complex situation where there are many interrelated key characteristics, where there are numerous classes, and a large number of items, it is difficult for management to anticipate all of the effects of a procedural, policy, or technical change. One of the merits of linear programming is that it provides a way of measuring the chain effects of one or more administrative actions or technical changes.

For example, if management has a single factory with one warehouse in the East and one in the West, each carrying a complete line of products, then it is easy to determine for any given customer from which warehouse to ship any order so that shipping costs are minimized. However, if management has several factories and scores of warehouses a problem will arise immediately as to how much each factory should ship to each warehouse in order to minimize shipping costs.

Complex situations can easily get out of hand because of the sheer magnitude of the number of possible paths or courses of action. Consider the following examples:

- 10 warehouses and 500 customers involve 5,000 possible shipping routes
- 20 products and 50 machines involve billions of possible ways of scheduling the products if every machine can make every product
- 25 products and 50 raw materials involve a maximum of 1,250 allocations
- 64 districts and 25 types of tax returns involve 1,600 allocations of manpower for examining purposes only.

The method is mathematical and a form of matrix analysis. Examples of matrix analysis in orthodox

statistical methods include linear regression, nonlinear regression, discriminant functions, and factor analysis. However, it can be considered broader in a way than these techniques because it obtains answers subject to technical and managerial conditions and limitations.

This type of matrix analysis calls for the formulation of the problem in terms of one or more linear or straight-line relationships, for the quantification of certain restrictions or restraints which exist or which must be imposed, and for the formulation of some maximizing or minimizing function. If these, and certain other conditions are met, then a unique solution of the problem can be obtained. If the relationship is nonlinear, then it is possible to use a linear relationship as a first approximation. However, research on nonlinear functions is progressing so that some think the term "linear" programming is too narrow, and hence are suggesting a more general term such as "mathematical programming."[1, 2]

An administrator uses very simple linear methods in order to solve certain problems. When he says that with twice as many personnel he will need twice as much office space, and twice as many typists, and twice as much paper, he is using simple linear relations to solve a problem. Many of these linear relations may be used as the basis of decisions without the administrator becoming aware of the fact that he is using linear methods. Linear programming enables the administrator to go much further than these simple relations and to deal explicity and quantitatively with problems involving not only many variables but several conditions and restraints as well, where it is difficult if not impossible to make the proper allowances on the basis of intuition or experience.

Despite the fact that linear programming is most useful and effective in solving complex problems which cannot be solved in any other way, it can also be applied to some very simple ones, or to certain parts of a complex problem. The purpose of this article is to illustrate by means of fairly simple, but still quite realistic problems, just how the method is applied. It is kept simple in order that elementary arithmetic and algebra can be applied, and in order that the solutions in three instances can be illustrated on simple graph paper. In this way it is hoped to indicate how the method can be applied to more complex problems, such as those discussed in the list of references attached.

A Travel Problem

Assume that a person desires to make a trip of at least 1,000 miles, and that he has to use both a bus and a train. Assume that the average speed of the bus is 40 miles per hour, while that of the train is 50 miles per hour. Assume further that the traveler cannot spend more than ten hours on the bus nor more than 15 hours on the train. Assume also that the travel cost per hour is twice as much on the train as on the bus. The problem is to determine how many hours to travel by bus (x_1) and by train (x_2) so that the total transportation cost (to a passenger) is minimized.

We can formulate the problem in quantitative terms as follows:

1. Basic relationships and conditions
   a. $40\ x_1 + 50\ x_2 =$ distance (which must equal or exceed 1,000 miles)
   b. x_1 has to be equal to or less than 10 hours ($x_1 = 10$)
   c. x_2 has to be equal to or less than 15 hours ($x_2 = 15$)
2. Minimizing function
   a. $x_1 + 2x_2 = a =$ total cost (which must be a minimum)

The graphic solution of this problem is shown in Fig. 1. First we plot on regular graph paper the straight line $40\ x_1 + 50\ x_2 = 1{,}000$. Then we draw the lines $x_1 = 10$ and $x_2 = 15$. These three lines intersect and form the triangle ABC, any point within which meets the conditions of the problem: the distance must equal or exceed 1,000, the hours on the bus must be ten or less, and the hours on the train must be 15 or less.

This means that there are an infinite number of solutions since there are an infinite number of points within the triangle. We obtain a unique solution by making use of the minimizing function, which can be written as follows: $x_1 = -2x_2 + a$. This is a family of straight lines of slope -2 since the value of **a** is not specified. We imagine that this family of lines is drawn on the chart; one such line in the family is shown. Then we find where the line in this family intersects the triangle and at the same time the intercept **a** has the least value. This is at point A. Hence, the values of x_1 and x_2 at this point will meet all of the conditions of the problem including that of the minimizing function. These values are: $x_1 = 10$ hours, and $x_2 = 12$ hours. Substituting these values in the distance equation gives 1,000, while substituting them in the cost function gives 34. Other values of x_1 and x_2 will give a smaller value for cost, but they will not meet the other conditions of the problem.

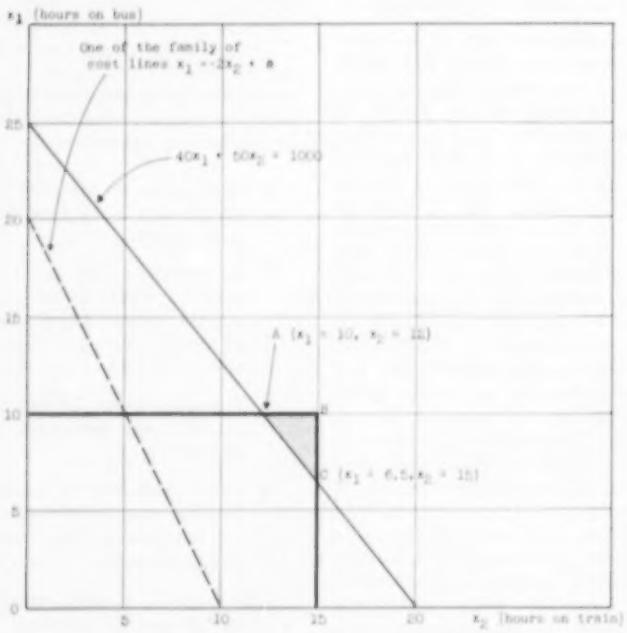

Figure 1—Graphic Solution of the Travel Problem

This problem differs from the orthodox problem in time, speed, and distance in several ways. Certain limitations are placed upon both variables and constants; this leads to the use of inequalities as well as to the use of equalities. Furthermore, a minimizing function is introduced in order to obtain a unique solution, since the use of inequalities leads to boundary conditions which include an infinity of solutions.

It is interesting to note that if the cost function were the reverse, that is $2\ x_1 + x_2 = a$, or $x_1 = -\frac{1}{2}\ x_2 + a$, then the cost line would have a minimum value of **a** when this line passed through point C, and the answer under these conditions would be $x_1 = 6.5$ hours, and $x_2 = 15$ hours. What this means is that if the slow method of travel is also the most costly, then one will tend to spend the maximum allowable time on the fast method: in this case 15 hours.

It is important to note also that if the slope of the cost function is exactly the same as that of the distance function, that is -1.25, then any point on the line between points A and C would satisfy all of the conditions. In such a case whether one selected the values of point A or the values of point C, or the values of some point between them, would be decided on some other basis.

In the foregoing problem if the slope of the cost function exceeds -1.25 then point A will be selected, while if the slope of the cost function is less than -1.25 point C will be selected. The slope of the first cost function is -2 so point A is selected, while the slope of the second cost function is $-\frac{1}{2}$ so point C is selected.

A Tax Problem

One of the major difficulties encountered in applying linear programming is that of defining the problem. This is difficult for several reasons. In the first place there are many ways of stating the same general problem since it usually has many aspects. There are many different ways of measuring relative effectiveness. Much will depend upon what characteristic or characteristics are to be minimized or to be maximized. Furthermore, one must guard against the tendency to force a problem into the linear programming mold just for the sake of making linear programming applicable. It is necessary therefore to make a realistic analysis of the problem; this requires close cooperation with administrators and other specialists familiar with the problem.

However, this should not prevent one from applying linear programming to the more simple aspects of a complex problem, particularly in the initial stages of application. By gaining experience in applying the method to the simpler aspects, it will be possible to do a much better job in defining and solving more complicated problems.

In order to illustrate how the method can be applied to a common type of problem, we have selected the problem of determining how to allocate hours of work as between field examinations and office audits of tax returns. The relationships and conditions and data (which are fictitious) are given below. It is obvious that the solution of this problem, or any other, can be no better than the relationships, conditions, and data from which it is derived.

Type of tax return	Tax change per hour		Minimum amount of tax change to be corrected
	Field	Office	
A	$100	$125	$ 750
B	330	100	1,500
C	100	60	600

It is assumed that we set as our goal a certain amount of tax error (in dollars) to be corrected for each of the three types of tax returns. It is assumed that we know or can estimate the average amount of tax change per hour for each type of return for each type of examination, and the cost per hour for field audit relative to the cost per hour for office audit. For purposes of illustration it is assumed that it costs three times as much per hour to make a field audit as to make an office audit.

We want to determine how to allocate hours of work as between the two kinds of audit, given the relationships specified with the proviso that total cost must be a minimum. Let x_1 stand for the hours to be spent on field audits and x_2 for the hours to be spent on office audits. Then we have the following relationships:

For type A returns:
$100\ x_1 + 125\ x_2 = 750$

For type B returns:
$330\ x_1 + 100\ x_2 = 1{,}500$

For type C returns:
$100\ x_1 + 60\ x_2 = 600$

Also $3\ x_1 + x_2 = a$ (must be a minimum)

The graphic solution is shown in Fig. 2. We draw the three lines of relationship using equalities, one for type A returns, one for type B returns, and one for type C returns. These three straight lines intersect as shown in Fig. 2. The heavy broken lines ABCD show the boundary conditions: any point below these lines will not meet the conditions, any point above these lines will. A unique solution is obtained by imposing the cost function which must be minimized; that is the value of the

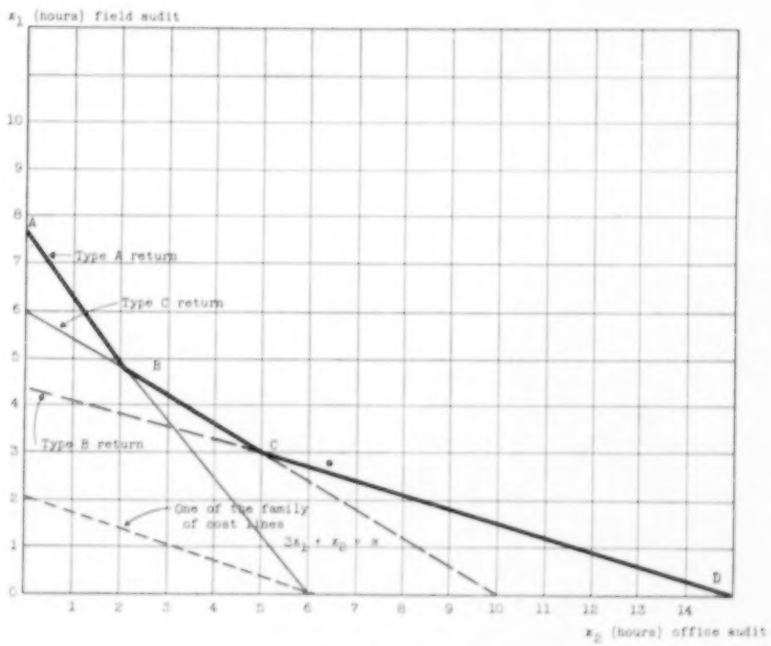

Figure 2—Graphic Solution of the Tax Problem

intercept a must be a minimum. This value will be a minimum, when all other conditions are met, when the cost line passes through point C. Hence, the desired values are $x_1 = 3.1$ hours, and $x_2 = 4.9$ hours. Note that these values represent the point of intersection of the lines for type B returns and type C returns, and hence can be obtained by solving simultaneously the two equations for these lines.

These values show that for every eight hours spent examining these three kinds of returns 3.1 hours should be spent on field examinations and 4.9 hours spent on office audits, in order to meet the specifications given. Note that this ratio applies to each of the three types of returns, and that it is assumed that the supply of each type of return will not be exhausted. Furthermore, this ratio is not changed if the minimum amount of tax change in each case is any constant multiple of the amount given.

An Automobile Production Problem

In the preceding problem interest centered in meeting minimum quotas with the minimum cost. In the present example, adapted from one used by Dorfman, [2] interest centers in obtaining balanced production but with gross profit maximized. The method and procedure are essentially the same as that given in the preceding example.

Suppose that an automobile manufacturing company has capacity to produce automobiles and trucks, and that the capacity is interchangeable. (A more realistic situation might be one in which the manufacturer can make two models of the same basic automobile.) The capacity for stampings is equivalent to 25,000 automobiles or 35,000 trucks per month. The engine capacity is 30,000 engines for automobiles or 20,000 for trucks. Assembly capacity is 15,000 trucks or 23,000 automobiles. The gross profit is $300 per automobile and $250 per truck.

The problem is one of determining how many automobiles and how many trucks should be manufactured each month in order to maximize gross profit. The basic equations are as follows: where x_1 (automobiles) and x_2 (trucks) are in units of 1,000:

$$\text{Stampings:} \quad 35\,x_1 + 25\,x_2 = 875$$

$$\text{Engines:} \quad 20\,x_1 + 30\,x_2 = 600$$

$$\text{Assembly:} \quad x_1 = 23$$

$$x_2 = 15$$

Maximizing function:

$$300\,x_1 + 250\,x_2 = p$$

The first two equations are derived on the assumption that capacity is perfectly interchangeable between the two products.

The graphic solution is shown in Fig. 3. The number of automobiles x_1 is plotted vertically, and the number of trucks x_2 is plotted horizontally. The first four equations are plotted on the chart, and form the critical boundary line ABCDE, consisting of four segments. The gross profit function will have a maximum value of p, at the same time that all other conditions are being met, when it passes through point C. Hence the values of x_1 and x_2 for the point C are the values desired: they are 20,500 automobiles and 6,400 trucks respectively. This leads to a maximum gross profit of $300 \times 20{,}500 + 250 \times 6{,}400$ or $7,750,000.

Note that the values of x_1 and x_2 can be obtained by solving simultaneously the first two equations. In this way the values desired can be obtained algebraically.

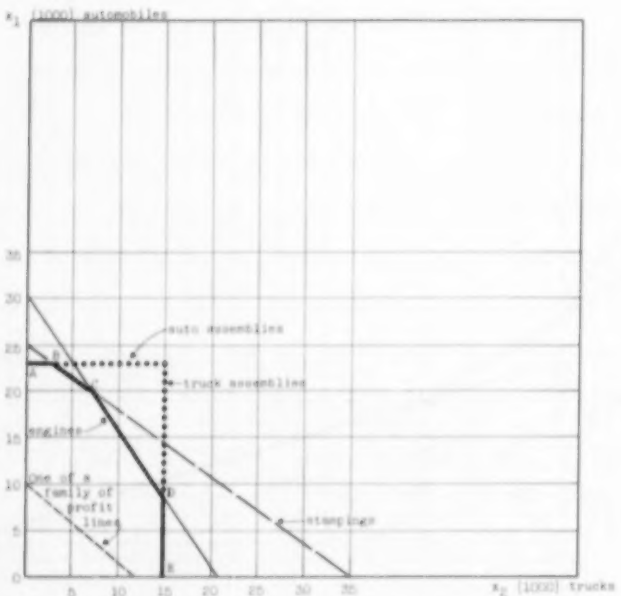

Figure 3—Graphic Solution of the Automobile Production Problem

A Shipping Problem

A more complicated problem which has been attacked by means of linear programming is the shipping or transportation problem.[1] The nature of this problem can be stated as follows: given the capacity of each of a number of factories scattered over a geographical area, and given the requirements of a number of warehouses (or customers), what amounts should be shipped from each factory to each warehouse or customer so that capacity levels are attained and requirements are met, but at the same time the shipping costs are kept at a minimum?

In order to illustrate the procedure followed in solving this type of problem we shall consider a simple but fictitious problem in which two factories furnish products to four consuming units, such as warehouses or stores. The capacity of the factories, the requirements of the warehouses, and the cost of shipping per unit of product from each factory to each warehouse, are given in Table I. The problem is how to distribute the capacity production to the warehouses so that the requirements of the latter will be met, but with the minimum total amount of shipping cost.

TABLE I—Basic Data

Warehouse	Shipping cost per unit		Requirements (units)
	Plant 1	Plant 2	
A	$16	$13	3,000
B	20	29	5,000
C	40	38	8,000
D	37	49	2,000
Capacity (units)	10,000	8,000	18,000

The solution of this problem is simple and can be worked out very easily but a more general method will be applied because it can be employed to solve complex problems where the solution is not so easy nor so obvious. The procedure is given in several steps.

First we make a tentative or trial allocation of total production to plants and warehouses making sure that the marginal totals for each plant and each warehouse are the same as those given in Table I. Assume the following trial allocation:

	Plant 1	Plant 2	Total
Warehouse A	0	3,000	3,000
B	0	5,000	5,000
C	8,000	0	8,000
D	2,000	0	2,000
Total	10,000	8,000	18,000

Second, set up the shipping cost data to correspond.

	Plant 1	Plant 2
Warehouse A		13
B		29
C	40	
D	37	

Third, construct a set of marginal cost values based upon an assumed value of 00 for the first row, and the lowest cost values in each column. Each cell value must equal the sum of its two marginal values; for example 29 = 16 + 13, and 40 = 03 + 37. The entire table must be consistent internally.

	Plant 1	Plant 2	Row marginal values
Warehouse A		13	00
B		29	16
C	40		03
D	37		00
Column marginal values	37	13	

Fourth, fill in the empty cells in the foregoing cost table by adding marginal values corresponding to each such empty cell. In the first cell we obtain 00 + 37 or 37, in the next cell we obtain 16 + 37 or 53, in the next cell 03 + 13 or 16, and in the last cell 00 + 13 or 13. This leads to the following table of costs where the underlined values are those corresponding to the trial selection of routes.

	Plant 1	Plant 2
Warehouse A	37	13
B	53	29
C	40	16
D	37	13

Fifth, find the cell in the foregoing table where the entry exceeds the original shipping cost value by the greatest amount. This is 53 in the cell B-1; this is 33 larger than the original value of 20. This is the cell where the greatest savings in shipping costs can be made.

Sixth, let x be the amount of product to be entered in cell B-1, and adjust other cell values so as to maintain the original marginal totals. This means that if we add x in cell B-1 we must subtract x in cell B-2 in order to maintain a row total of 5,000. Similarly we must subtract x in cell C-1 in order to maintain a column total for plant 1 of 10,000. This means that in turn we must add x in cell C-2 in order to keep the marginal total for C and for plant 2 at 8,000.

We cannot adjust the value of 3,000 in cell A-2 because this is exactly the amount that warehouse A requires; similarly we cannot adjust the value of 2,000 in cell D-1 because it is exactly the amount that warehouse D requires. Hence, the adjustments involving x are limited to warehouses B and C.

	Plant 1	Plant 2	Total
Warehouse A		3,000	3,000
B	x	5,000—x	5,000
C	8,000—x	x	8,000
D	2,000		2,000
Total	10,000	8,000	18,000

Seventh, solve for x. Find the cell where a shift will result in maximum savings and still maintain marginal totals, and set it equal to 0. This means setting 5,000 − x = 0; hence x = 5,000. Reconstruct the initial trial table of allocations, and obtain the following:

TABLE II—Final Allocation

	Plant 1	Plant 2	Total
Warehouse A	0	3,000	3,000
B	5,000	0	5,000
C	3,000	5,000	8,000
D	2,000	0	2,000
Total	10,000	8,000	18,000

Eight, set up the corresponding cost table, construct marginal values, fill in the empty cells, and determine whether any entries in these latter cells are larger than the original values.

	Plant 1	Plant 2	Row marginal values
Warehouse A	15	13	00
B	20	18	05
C	40	38	25
D	37	35	22
Column marginal values	15	13	

In constructing marginal values we assign 00 to the first row and 13 to the second column. This immediately leads to 25 for row C and 15 for column 1 since 40 is in cell C-1. This leads in turn to 05 for row B and 22 for row D. Then the empty cells were filled in: A-1 = 00 + 15 = 15, B-2 = 05 + 13 = 18, and D-2 = 22 + 13 = 35. Since there were two entries in row C, this row dominated, and had to be satisfied first.

It will be observed when the comparisons are made with cost values in Table I that all values in empty cells are now less than the corresponding values in Table I: 15 is less than 16, 18 is less than 29, and 35 is less than 49. This means that we now have the allocation which will result in the minimum total shipping cost (Table II).

If in making the foregoing test any empty cell is found with a cost value larger than the corresponding value given in Table I, then the procedure outlined above is repeated; actually the procedure is repeated until all cost values in the empty cells are less than the corresponding values in the basic table (Table I).

References

Note: The first two references are recommended for the nonmathematical reader.

A. References emphasizing applications

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2. R. Dorfman, "Mathematical or 'linear' programming," *American Economic Review*, vol. XLIII, Dec. 1953, pp. 797-825
3. Joseph A. Joseph, "The application of linear programming to weapon selection and target analysis," Operations analysis technical memorandum No. 42, U.S.A.F. Headquarters, Washington, D. C., 1954
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5. Earl R. Swanson and Kirk Fox, "The selection of livestock enterprises by activity analysis," *Journal of Farm Economics*, vol. XXXVI, Feb. 1954, pp. 78-86
6. A. Charnes, W. W. Cooper, and B. Mellon, "Blending aviation gasolines—a study in programming interdependent activities in an integrated oil company," *Econometrica*, Apr. 1952, p. 135
7. A. Charnes, W. W. Cooper, and D. Farr, "Linear programming and profit preference schedul-

ing for a manufacturing firm," *Journal of the Operations Research Society of America*, vol. I, May 1953, pp. 114-129 (errors in Tables II and IV)

8. A. Charnes, W. W. Cooper, and B. Mellon, "A model for programming and sensitivity analysis in an integrated oil company," *Econometrica*, vol. 22, Apr. 1954, pp. 193-217
9. T. C. Koopmans, editor, *Activity Analysis of Production and Allocation*, John Wiley and Sons, New York, 1951
10. *Operations Research for Management*, edited by J. F. McCloskey and Florence N. Trefethen, Johns Hopkins Press, Baltimore, Md.

B. References emphasizing the mathematics of linear programming

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    Part I. Dantzig, Orden, and Wolfe. "The generalized simplex method for minimizing a linear form under linear inequality restraints."

    Part II. Dantzig and Orden, "Duality theorems."

    Part III. Dantzig, "Computational algorithm of the simplex method."
17. *Proceedings of the Second Symposium on Linear Programming*, Washington, D. C., Jan. 27-29, 1955. 2 vols. National Bureau of Standards and US Air Force.

Local Section News

". . . BUT NOT FORGOTTEN"

ALBUQUERQUE On Jan. 18 the section attended an exhibit and lecture on "Civilization through tools" in a joint meeting with members of the New Mexico Council of Technical and Scientific Societies. This exhibit, which was presented by the Wilkie Foundation of Des Plaines, Ill., covered the development of tools embracing an estimated time span of one million years.

ALLENTOWN -BETHLEHEM The first class of the section's "Practice of quality control" course was scheduled to start on Jan. 9; however, this class was cancelled because of a severe ice storm in the area. The following Monday, Jan. 16, the class got off to a better start with 37 members registering for the course. Miss Bonnie Small will again be the instructor with four members of the section assisting.

A plant tour of the Carpenter Steel Co., Reading, Pa., on Jan. 11 was enjoyed by 57 members and guests. A dinner at Leshers Hotel in Reading preceded the tour. Chairman Dave Roberts conducted the business part of the meeting and G. Brumbach gave a short talk about the products and plant facilities of the Carpenter Steel Co.

BALTIMORE The January meeting was held at the Johns Hopkins University. Our guest was E. G. Paterson, director of quality assurance, Bell Laboratories, New York, N. Y. Mr. Paterson's subject was "The Bell system of quality assurance plan." Before the talk, the officers and executive committee had dinner with Mr. Paterson as our guest at the Hopkins Faculty Club.

BINGHAMTON On Jan. 10 R. M. Hofstead of Bristol Lab., Inc., Syracuse, N. Y. spoke on "Design of experiments." Everyone in attendance enjoyed Mr. Hofstead's fine presentation.

The section is again sponsoring a course in basic quality control at the Union-Endicott High School. The course will last for 12 weeks and the instructors are Charles H. Rubin and John Schneider.

BIRMINGHAM At the January meeting, R. V. Flint, chief industrial engineer-basic standards, U. S. Steel Corp., Pittsburgh, was guest speaker before an audience of nearly 200 persons. Mr. Flint's talk was on the subject "Multiple correlation of blast furnace variables." He described how punched card tabulating equipment had been used to do much of the calculations involved in the analysis of 10,000 observations to determine the effect upon blast furnace coke usage of approximately 15 significant variables. This joint meeting was the largest in the history of the section.

Twenty-three students are enrolled in the section's course on quality control in which six of the section's members are participating as instructors and lecturers.

BUFFALO On Jan. 30 a problem clinic concerning components of variance, sampling inspection, and work measurement for incentive payment, was held at the University of Buffalo. Featured guest speakers were M. Dale Fimple, Bell Aircraft Corp.; Alvin R. Haven, Trico Products, Inc.; and F. V. Herr and P. Sheehe of Dayton Malleable Iron Co.

BUZZARDS BAY Jack C. Werner, senior associate of Werner Textile Consultants in Larchmont, N. Y. and Atlanta, Ga., was main speaker at the Jan. 10 meeting held in the Continental Screw Co. in

New Bedford. A well attended dinner at the New Bedford Hotel preceded the meeting with members and guests coming from Fall River and Taunton. Mr. Werner's subject was "Management-communications." He indicated how management will be drawing increasingly on the specialized knowledge of mathematicians, psychologists, semanticists, and social scientists in composing effective patterns of communications.

The section is sponsoring a basic course in quality control consisting of eight-two hour lectures given at Berkshire-Hathaway in New Bedford. Among the instructors are Peter Freedman, Kenneth V. Chace, Walter Nichols, and William Hammerly.

CINCINNATI Instead of holding a regular meeting in January, all section activity was centered on the 5th annual all-day conference held in the Hotel Sinton on Jan. 28. This conference was somewhat different from the four previous ones in that it was arranged around a workshop type of program. These workshops were six in number, each devoted to a separate major field of interest, namely aircraft, electrical equipment, metal products, foods, chemicals, and pharmaceuticals, administrative applications, and paper and fibre. Each workshop was directed by a well known authority in each field of endeavor.

All agreed that this was one of our most interesting and successful conferences to date.

CINCINNATI Hamilton Subsection The regular monthly meeting was held on the evening of Jan. 11 in the main conference room of the Whirlpool-Seegar Corp., Estate Division, with Don Markel, Bob Merrill, and Paul De Selms of that company acting as hosts.

In spite of the inclement weather, a fair size group attended the meeting and all enjoyed the "down-to-earth" talk by Ken Henry, general superintendent of manufacturing, G. H. R. Foundry Division of Dayton Malleable Iron Co., Dayton, Ohio.

Mr. Henry, vice chairman of the Dayton section, spoke on the subject "Quality control in the foundry" and elaborated on the use of this relatively new SQC technique as a management tool to generally improve industrial organization and management in all its phases.

CORNING -ELMIRA James L. Huff of Optical Gaging Products, Rochester, N. Y. delivered a lecture on "Inspection by optical projection methods" at the Jan. 10 meeting of the section held in Corning. Approximately 75 members and guests were present as Mr. Huff showed movies and slides in order to demonstrate the various types of optical gauges used in industry.

DALLAS -FORT WORTH The regular technical meeting was held on Jan. 12. The program consisted of a panel discussion, on the subject, "Reliability and quality control." Panel members were H. B. Epstein and M. R. Seldon, Chance Vought Aircraft, and R. J. Hendrickson and H. D. Bradshaw, Convair-Fort Worth Division. Dr. A. W. Wortham, Chance Vought Aircraft, acted as moderator.

Outcome of the section-sponsored training course "Basic instruction in statistical quality control," which will be concluded Feb. 21 was most gratifying. Applications for 82 new members have been submitted to the national office as a direct result of this training school.

DANVILLE -SUNBURY The January meeting featured a joint meeting with the Central Pennsylvania section of the American Chemical Society at Bucknell University on Jan. 17. Dr. Lewis Fowler of Monsanto Chemical Co., St. Louis, Mo., impressed everyone with his talk on "Precision and accuracy in chemical measurements."

DELAWARE Norbert L. Enrick, associate professor at the Institute of Textile Technology at Charlottesville, Va. was the principal speaker at the January meeting. In his talk on the subject "Process to process variations analysis," Prof. Enrick presented a comparatively new, simplified statistical technique for determining within-machine and between-machine variation in the subsequent processing stage for comparison with actual performance.

DENVER The section met at the Town House Supper Club in Aurora, Colo. for the Jan. 12 meeting. Following a fine dinner, Henry J. Jacobson gave a significant presentation of the subject, "Quality control by infiltration." Mr. Jacobson is a Fellow and a national director of the society and is presently the quality control manager of the Schaible Co., Cincinnati. His wide experience and technical background provided the section with one of the best programs of the year.

GEORGIA The fifth regular meeting of the Atlanta group listened attentively to a talk on "Queuing (waiting line) theory" by Dr. J. J. Moder, Jr. of Georgia Institute of Technology. This program had to be changed at the last minute due to the illness of Dr. George M. Brown, of the Georgia State College of Business Administration.

The basic course in quality control that is being given each Monday night at Georgia Institute of the Technology has 33 students being taught by Donald S. Holmes. This is to be followed by a basic course in statistics, also in the School of Industrial Engineering.

ERIE On Jan. 11 Herbert Mitchell of Turco Products, Inc. presented a program entitled "Flaw location." A scheduled sound motion picture failed to arrive —grounded at the Chicago Airport due to weather. Herb's lively demonstration made for one of the better meetings.

GREATER MUSKEGON Arthur Bender, Jr., president of the society, addressed the section members at a dinner meeting held at Bill Stern's Steak House. Approximately 75 members and guests from Muskegon and the Grand Rapids section attended. Mr. Bender's topic "Qwik-C" or a graphical method of determining the characteristics of a frequency distribution, was well received and was followed by a question and answer period. After the meeting, Mr. Bender met with the Greater Muskegon board members to greet them personally and brief them on ASQC activities.

INDIANAPOLIS Walter Blickle of the Cummins Engine Co., Columbus, presented a spirited discussion titled "A new look" at a quality control program on Dec. 13. This talk was about how Cummins, with a well developed successful quality control program took a "new look" and embarked on a new program to attain even better quality of design and better quality of conformance in the future. The slides, showing Cummins Diesels at work in primitive countries

gave the audience a dramatic understanding of the reliability such equipment must possess.

The "Indiana Clinic" offered by the section on Jan. 27 at Butler University was so successful it will become an annual affair. The program was planned to attract wage incentive and administrative people to membership in the society. The interest was evidenced by the 95 percent paid in advance sale of reservations. The effectiveness, membershipwise, is not known at this time.

Dr. J. M. Juran delivered the main address at the banquet. Dr. Juran's talk was entitled "Quality control grows up." His message might be summarized as an appeal to quality control men to attack the important problems, the problems that demand leadership, since the solution can only be reached through the joint effort of many people, and to spend less time devising elegant solutions for minor problems.

Over 225 people attended the clinic, with visitors coming from four states. It was co-sponsored by Butler University, the Society for Advancement of Management, The Indianapolis Chamber of Commerce, and the Retail Merchants Association of Indianapolis.

INDIANAPOLIS Columbus Subsection On Jan. 12 J. Edward Hoagland, quality manager of the Indianapolis plant of the Radio Corp. of America spoke on "Quality control in the electronics industry." Mr. Hoagland explained the manufacturing processes and the quality control techniques used to insure quality vacuum tubes for the radio and television industry.

KANSAS CITY Lloyd A. Knowler of the University of Iowa was the guest speaker at the Jan. 11 meeting. Following the dinner and business meeting which was held at the Blue Hills, Mr. Knowler presented in his usual entertaining style, his subject "Statistical quality control."

LOS ANGELES The program of the January meeting of the section was conducted by personnel of Northrop Aircraft, Inc. R. S. Catlin, director of quality control and Jack Mannion, assistant director of quality control, presented Northrops answer to the reliability problem. This answer provided an excellent unit history and made a surveillance inspection program extremely practical and positive in many areas where only 100 percent inspection had been used in the past.

MICHIGAN The dinner meeting and dance, scheduled for Jan. 21 was held as planned at the Park Shelton Hotel, Detroit. Approximately 40 members attended with their wives, who were briefed on quality control methods suitable for home use by Dr. E. C. Yehle from the University of Michigan.

MICHIGAN Wolverine Subsection The January meeting was held at the Post Cereals Club House, Battle Creek, on Jan. 6. "Principles of acceptance sampling" was the topic discussed by Professor Gayle W. McElrath from the University of Minnesota. A fine crowd was on hand.

MINNESOTA The joint dinner meeting of the section and the Minnesota Industrial Chemists Forum was held at the Curtis Hotel in Minneapolis on Jan. 17 and was a huge success. The social hour preceding the dinner got the two groups acquainted and after a fine dinner, Dr. Youden, who is a statistical consultant for the National Bureau of Standards in Washington, D. C., spoke on the subject "Getting the most out of your industrial experiments."

A lively discussion and question period followed his talk where many interesting points were covered.

MONTREAL At our regular meeting on Jan. 18 which was attended by 54 members, J. C. Lafforque of the Canadian General Electric Co. delivered an address on "Master control system." The subject matter was excellent and new and created considerable interest, as was evidenced by the long question period.

PITTSFIELD On Jan. 5 the section held its annual ladies program designed to appeal to the wives of section members as well as to their husbands. Twenty couples made an interesting tour of the main plant of the Berkshire Woolen Co., Pittsfield, in the afternoon. After dinner at the Stanley Club, a motion picture produced by J. C. Penney Stores, Inc., "Quality control in the merchandising field," was shown. This film, which gives a picture of certain quality problems faced by department stores, and some solutions which have been found, was enjoyed by all present.

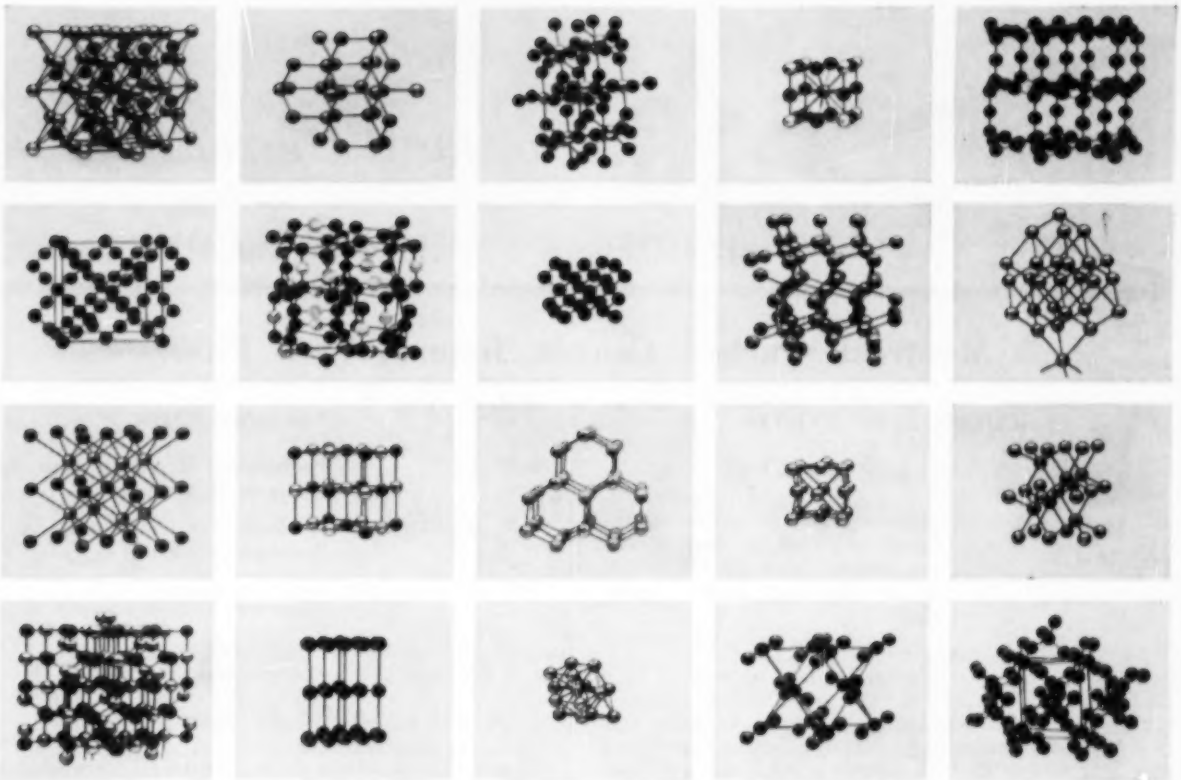
ST. LOUIS The Ford-Mercury's local Mercury division played host to 86 members of the local section and their guests for a long and most enjoyable tour of their operation. The exotic color combinations of the new models created a potential market for many participating in the tour.

A training course in "Sampling by attributes and variables" is now in session and will continue through Apr. 13. Educational programs such as this one have and will continue to further the training of quality control people in the St. Louis area to unmeasurable limits.

SCRANTON -WILKES-BARRE Our regular meeting was held on Jan. 18 at the Scranton YMCA with Commander R. E. Spreen, U. S. Navy, as guest speaker. Commander Spreen is assistant director of the quality control division of the Bureau of Ordnance. Under the division director, he is responsible for the quality of all material procured and stored by the Bureau of Ordnance.

He gave a 40 minutes talk on the "Bureau of Ordnance quality control system," including organization procedures, relations with industry, present problems, and future trends. Following his talk was a 60 minute question and answer discussion.

SYRACUSE The Industrial Management Club of Auburn is sponsoring a course of study in "Applied techniques of elementary quality control" in co-operation with the Syracuse section and the Adult Education Group of Auburn. The instructor, Richard Holmes, is one of four instructors provided by the section to teach in the Syracuse area. Three phases of statistical quality control are being taught. They are basic, advanced, and special problems. Outside the city of Syracuse itself and Auburn, a course is being taught in the nearby town of Fulton. Other instructors are Frank Winne, Al Edgar, and Brad Vineall. There is a total of about 1000 participating in the program and it looks like it will be expanded even farther next year due to the diversity and growth of industry in the area.



Crystal structure models. Top row, left to right: cuprite, zincblende, rutile, perovskite, tridymite. Second row: cristobalite, potassium dihydrogen phosphate, diamond, pyrites, arsenic. Third row: caesium chloride, sodium chloride, wurtzite, copper, niccolite. Fourth row: spinel, graphite, beryllium, carbon dioxide, alpha-quartz.

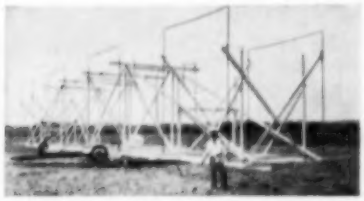
FROM ATOMS TO STARS

Research at Bell Telephone Laboratories ranges from the ultimate structure of solids to the radio signals from outer space. Radio interference research created the new science of radio astronomy; research in solids produced the transistor and the Bell Solar Battery.

Between atoms and stars lie great areas of effort and achievement in physics, electronics, metallurgy, chemistry and biology. Mechanical engineers visualize and design new devices. Mathematicians foreshadow new communications techniques.

Despite the diversity of their talents, Bell Laboratories scientists and engineers have much in common. A habit of teamwork channels these talents into great communications advances. These men have developed the world's finest telephone system. In doing so, many have become leaders in their fields. Opportunities for achievement await properly qualified scientists and engineers at Bell Telephone Laboratories.

Models of the atomic patterns in solids help Bell Laboratories scientists visualize their electrical behavior.



Directional antenna used by Karl G. Jansky in discovery of stellar radio signals at Bell Telephone Laboratories in 1932.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH • LARGEST INDUSTRIAL LABORATORY IN THE UNITED STATES

10th annual convention of
THE AMERICAN SOCIETY FOR QUALITY CONTROL

Montreal, Quebec, Canada June 6, 7, 8, 1956

SCHEDULE OF EVENTS

Tuesday, June 5, 1956

Registration—Advance registrants may pick up their tickets and credentials on the Mezzanine of the Sheraton Mount Royal Hotel

Wednesday, June 6, 1956

8:30 am	Registration—Lower floor, Le Palais du Commerce, 1650 Berri Street (10 minutes by taxi; special marked buses direct to Le Palais du Commerce from Sheraton Mount Royal and Laurentien Hotels)
8:30 am-12:15 pm	Exhibits—Get in early, before the crowd
11:00 am-12:00 noon	Technical Sessions
12:15 pm	Luncheon
1:15 pm-5:30 pm	Exhibits—See the ones you missed
2:00 pm-4:30 pm	Technical Sessions
4:35 pm	Annual Meeting ASQC—Mezzanine, Le Palais du Commerce
9:00 pm	Social Evening—Champlain Room, Sheraton Mount Royal Hotel

Thursday, June 7, 1956

8:30 am	Registration—Lower floor, Le Palais du Commerce
8:30 am-12:15 pm	Exhibits—All the latest things in the Quality Control Field
9:30 am-12:00 noon	Technical Sessions
12:15 pm	Luncheon
1:15 pm-5:30 pm	Exhibits—Be sure you have not overlooked any
2:00 pm-4:30 pm	Technical Sessions
6:15 pm	Annual Banquet—Sheraton Mount Royal Hotel Ballroom

Friday, June 8, 1956

8:30 am	Registration—Lower floor, Le Palais du Commerce
8:30 am-5:00 pm	Exhibits—Your last chance for a thorough review
9:30 am-12:00 noon	Technical Sessions (There is no luncheon scheduled for today)
5:00 pm	Convention closes

LADIES PROGRAM

Ladies Headquarters during the entire Convention
Salon "B" on Mezzanine of Sheraton Mount Royal Hotel

Wednesday, June 6, 1956

9:00 am	Coffee Hour—Ladies Headquarters
12:30 pm-3:00 pm	Luncheon and Fashion Show Place: Normandie Room—Sheraton Mount Royal Guest: Miss Doreen Day—Fashion Consultant who will illustrate "Women's Fashions"
9:00 pm	Social Evening—Champlain Room, Sheraton Mount Royal (Not included in Ladies Registration. Tickets may be secured separately)

Thursday, June 7, 1956

9:00 am	Coffee Hour—Ladies Headquarters
1:00 pm-3:00 pm	Tour—Steinberg's Groceteria, Warehouse and Food Preparation Center (Buses will be provided) or Bus Tour—City of Montreal
6:15 pm	Annual Banquet—Sheraton Mount Royal Ballroom (Not included in Ladies Registration. Tickets may be secured separately)

Friday, June 8, 1956

9:00 am	Coffee Hour—Ladies Headquarters (The rest of the day has been left open for personal affairs, shopping, etc.)

WELCOME TO MONTREAL

THE PARIS OF NORTH AMERICA

Yes, Montreal, the Paris of North America and Canada's Convention City, will welcome you to your Tenth Annual Convention.

Plan to attend your Convention, to be held in Montreal **June 6, 7, 8, 1956**, and enjoy the attractions of this beautiful city. Make this event part of your annual vacation and bring along the rest of the family so they, too, may enjoy a holiday in Montreal. Here are five good reasons why it was decided to hold your Convention in Montreal and why you should plan to attend.

The City

Montreal is the metropolis of Canada; the island is the home of one-tenth of Canada's population. Founded in 1642 by Chomedey de Maisonneuve and called "Ville Marie," Montreal today holds enchanting relics of the French regime. Among these are: Place d'Armes, Notre Dame Church, the St. Sulpice Seminary, the Chateau de Ramezay, and Notre Dame de Bonsecours. Outside the old area of "Ville Marie" towers beautiful Mount Royal, a mountain inside a city, which today looks down on the second largest French-speaking city in the world and a great industrial and commercial center. Eight hundred miles from the Atlantic rollers, it is the second seaport of North America and the hub of the muti-million dollar St. Lawrence Seaway project.

Facilities

Montreal's hotels are all closely adjacent; and are all located in the center of the gayety and activity of the night spots and eating places. In Montreal's hotels you'll find the outstanding service, the courtesy, the hospitality, and comfort, as well as the friendly efficiency which have made them justly famous. Le Palais du Commerce, Convention Headquarters, is ideally located only 10 minutes from the hotels and offers all modern convention facilities: spacious meeting rooms, lounge areas, exhibits, and luncheons—all one one floor, under one roof.

Entertainment

Montreal is called the Paris of North America. It is a center of entertainment and night life and a gourmet's mecca for fine foods and rare wines. Throughout the City you will find hundreds of small, quaint restaurants serving all types of exotic dishes.

Beauty

Towering over the City stands Mount Royal with its many parks and playgrounds. Montreal has 250 parks and public squares, covering 2850 acres. The largest are Mount Royal, a delightful wooded area on the slopes of the mountain, St. Helen's Island in the middle of the St. Lawrence River, La Fontaine, and Maisonneuve. The famous caleches of Montreal—picturesque horse drawn cabs—can be seen everywhere showing the visiting tourist the beauty spots of Canada's metropolis.

Culture

Montreal is the home of McGill University, world famous school of medicine and engineering; also the Université de Montréal, Canada's largest French-Canadian center of culture. Towering over Montreal's skyline is the great silver dome of St. Joseph's Oratory on the shoulder of Mount Royal. To most of the 2,000,000 worshippers a year who throng the approaches to the shrine, it is better known as Brother André's Shrine, famous all the world over for its reports of miraculous cures of the sick and the afflicted who have prayed there.

These are but a few of the attractions and wonders of this great Canadian City. The Montreal Tourist and Convention Bureau has been set up specifically to answer any questions you may have about Montreal—they would welcome a letter from you. Just write to:

The Montreal Tourist and Convention Bureau
Suite M30
Sheraton-Mount Royal Hotel
MONTREAL, Canada

TENNESSEE
Memphis Subsection On Jan. 31 the section visited the Memphis works of the International Harvester Co. Douglas W. Ferris, quality control engineer, and his staff were hosts. Mr. Ferris illustrated a talk on "Changing control chart data to dollar values" by presenting the control chart techniques used in the fabricating departments, the foundry, receiving inspection, and service parts inspection. The meeting included a plant tour to show quality control in action.

TOLEDO Dr. E. Yehle, University of Michigan, gave an excellent talk on the subject of testing a curve for normalcy at the January meeting. The talk was preceded by an educational session given by Merrit A. Gates of our section.

WESTERN MASSACHUSETTS The Jan. 17 meeting was held at the Sheraton-Kimball Hotel in Springfield and was attended by 20 members and 15 guests. This was an open forum type meeting in which members presented case histories. J. Hinchen of Monsanto Chemical talked on "Rapid tests for correlation;" H. Busby of Ordnance Inspection presented a paper on "Process investigation in textiles;" M. Blew of Strathmore Paper —"Raw materials testing in paper;" and C. Bauman of Monsanto—"Analysis of variation."

The intermediate course in statistical quality control was completed on Jan. 25 after 15 sessions by 40 students of which seven took the course for college credit. This was a joint course in conjunction with the Massachusetts University Extension.

WICHITA On Jan. 3 William Collins, plant manager of Frontier Chemical Co., addressed the section on "Applications of quality control in the chemical industry." Approximately 100 members and guests were present at the dinner meeting.

WINNEBAGO No regular meeting was scheduled for the month of January due to road and weather conditions, but the officers and program committee held a planning meeting to map out the program for the first half of 1956.

WORCESTER Charles A. Reed, supervisor of quality control, Telechron Dept. of G. E. Co., Worcester, Mass., presented a talk on "A quality control technique for the establishment of finish specifications," at a meeting held on Jan. 19. His talk was very interesting and was enjoyed by all present.

YOUNGSTOWN W. J. Masser, manager of quality control engineering at General Electric Co. in Schenectady, N. Y., presented a fine talk on "Process capability study with a slide rule." His talk was well illustrated and was enjoyed by men from various industries. A special slide rule and form sheets were demonstrated to provide a simple and easy method to calculate standard deviations from frequency distributions.

Our educational chairman, Chester Smith, has just completed a ten week program on fundamentals of control chart techniques and sampling plan applications. The success of this educational program was measured by the fact that 11 new members were obtained as a direct result of these training sessions or a 25 percent increase in membership.

". . . CAST THEIR SHADOWS BEFORE"

ALBUQUERQUE The section meeting planned for Apr. 2, 7:30 pm, Mitchel Hall, University of New Mexico, will consist of both an educational session and a general meeting. The speaker for the educational session will be D. W. Ballard, Sandia Corp., who will discuss "The problem of the isolated lot." Dr. Leslie W. Ball, technical director of the United Electrodynamics Division, United Geophysical Corp., will be the guest speaker for the general meeting. Dr. Ball's topic will be "Inspection's relationship to quality control."

ALLENTOWN -BETHLEHEM On Apr. 11 the regular meeting will be held at Walp's Restaurant in Allentown. Burt P. Seipel, Studebaker-Packard Corp., Detroit, will speak on quality control at Studebaker-Packard.

BALTIMORE The section will hold a joint meeting with the Institute of Food Technologists at the Hotel Staffore. Dr. Howard Stier, chairman of the Washington section, will be our guest speaker.

BINGHAMTON On Apr. 3 G. A. Wilcox of the IBM Corp., Endicott, N. Y. will speak on "Vendor certification" and, as an added attraction, a tour will be made of the IBM Corp.'s Endicott plant.

BIRMINGHAM On Apr. 12 Dr. William Murray, director of Southern Research Institute, will speak on the use of statistical methods in research work. This well known privately endowed research organization is known throughout the South for its research on problems of Southern industry.

BUZZARDS BAY A. B. Mundel of the Sonotone Corp. in Elmsford, N. Y., will discuss "Vendor-certification" at the next meeting to be held on Apr. 10.

CENTRAL ILLINOIS The Central Illinois section is planning to hold a combined meeting with the Kankakee subsection and the participants in the Ninth Annual University of Illinois short course on quality control by statistical methods on Sat., Mar. 24 at the University of Illinois. Speakers to be heard at this meeting include: R. G. Fitzgibbons, Bendix Aviation Corp.; H. E. Maxwell, Caterpillar Tractor Co.; and Gayle W. McElrath, University of Minnesota.

CHICAGO On Mar. 20 the Calumet sub-group will hold their fourth dinner meeting at the Cape Cod Inn, located at 137th and Burnham, in Burnham, Ill., at 6:30 pm. The program chairman has announced that the guest speakers will be William Travers, project engineer of the Standard Oil Co. in Whiting, Ind., and Robert E. Franks of the Inland Steel Co. East Chicago, Ind.

Mr. Travers will speak on "Applications of poisson distribution in an oil plant," and Mr. Frank's topic will be "Statistical quality control in a coke plant."

On Apr. 5 the section will hold the introductory educational meeting at Navy Pier at 7:30 pm. R. L. Storer

will address the group on "Refinements, improvements and gadgets." Mr. Storer will discuss several relatively new developments in sampling inspection procedures as well as some old procedures under new names. This meeting should be a must on the calendar of those with sampling inspection problems.

On Apr. 18 the third of a group of plant tours arranged by our plant tour committee chairman E. G. Freund will be made through the Allied Chemical & Dye Corp. Format of the tour will be a talk on the application of statistical quality control techniques at Allied Chemical by a member of that plant.

CINCINNATI Robert I. Tenny of the Wahl-Henius Institute is scheduled to speak on "Statistical quality control in beer manufacture" at the regular meeting on Apr. 18.

CINCINNATI
Hamilton Subsection The group will meet on Mar. 7 at 7:30 pm at the Fisher Body Plant Adm. Bldg. Conference Room. Guest speaker will be Gordon Olson from the Ternstedt Div. of General Motors, Columbus, Ohio. His topic will be "Sampling."

CLEVELAND The section announces its second plant tour of the season on Apr. 6. Response to the first tour was very enthusiastic and the officers know that this tour will also be a success. The meeting is being held jointly with the Erie section and will consist of a plant tour through the Industrial Rayon plant in Painesville, dinner, and a panel discussion on "Incentives and quality control." Wayne Biklen of the American Safety Razor Co. will act as moderator.

Because of the tremendous success of the first course in "Fundamentals of quality control" that was presented last fall, it was decided to repeat the same course in March. Charles Kendel will again be the instructor and Hotel Carter will be the location of the classroom.

COLUMBUS On Mar. 21 Ervin F. Taylor, quality control analysis supervisor, North American Aviation, Inc., will talk about two statistical tools developed at North American to reduce the calculation efforts in solving problems using frequency distributions. Mr. Taylor has continually strived to simplify SQC principles in order to secure acceptance and application of the basic principle by all levels of production personnel.

On Apr. 18 a panel discussion on "What's your quality control problem?" will be held at the Jeffery Mfg. Co. This program is designed to provide a panel of four members to answer any questions that the audience wishes to put before them.

CORNING -ELMIRA The section will meet in Elmira on Apr. 10 to hear Leon Bass, manager of quality control, General Electric Co., Cincinnati, Ohio speak on "Quality control in the electronics industry." Mr. Bass is a vice president of the society.

DANVILLE -SUNBURY On Mar. 23 Edward P. McMahon of Nickey Brothers, Inc., Memphis, Tenn. will be the guest speaker. His topic will be "Statistical quality control woodworking applications."

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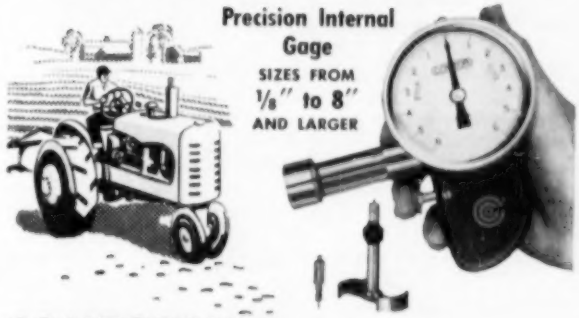

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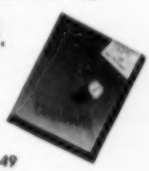

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DAYTON The Apr. 12 meeting will feature a plant tour of the Standard Register Co. Harold F. Ross, supervisor of quality control at Standard Register and an active member of the section, will be the host and guest speaker for the occasion.

DELAWARE The April meeting will be held at the Lord De La Warr Hotel on Apr. 5 and will feature a talk by D. L. Lobsinger, superintendent of quality control, United Air Lines, Inc., Denver, Colo., on "SQC applied to administrative areas." The educational clinic preceding this meeting will be on the subject of "Control charts for attributes."

ERIE On Apr. 6 we are holding a joint meeting with the Cleveland section. This will consist of a tour of Industrial Rayon, a dinner at Hellriegel's famous restaurant, and a panel concerning "Incentives and quality control" under Wayne Biklen of American Safety Razor Co. Dave Ferrell is working on Erie's end and is cooperating with Cleveland's Wendell Abbott.

GEORGIA "Purchaser-vendor relations in quality control" will be presented by H. B. Townsend, director of quality control, Scripto, Inc., Atlanta, at the regular monthly meeting of the Atlanta group to be held Tuesday, Mar. 27, at 7:45 pm in Room 1833 of the Hurt Building. At this meeting, the annual election of officers will be held.

INDIANAPOLIS On Mar. 20 Dr. E. P. King, research statistician, Eli Lilly, will present a timely subject at the afternoon session. Frank Caplan, Jr., supervisor of quality engineering, G. E. Co., Cincinnati, Ohio, will talk on "Quality control at General Electric Co." during the evening program.

KANSAS CITY The April meeting will be held at the Blue Hills Restaurant on Wednesday, the 11. James M. Barrabee, general foreman, International Harvester Co., Milwaukee, Wis., will present to the members the subject "General aspects of quality control in the Harvester Co."

MICHIGAN "What makes a quality control program successful?" will be the subject of a meeting to be held Apr. 4 at the Michigan State University. The speaker for the evening is Kermit C. Brown, superintendent of the QC department for American Seating Co., Grand Rapids. This program is being sponsored by the Wolverine Subsection.

On Apr. 20 at the Rackham Building in Ann Arbor, Robert D. Muir's subject will be "Lot plot in a job shop." Mr. Muir is chief inspector for Lundberg Screw Products Co.

MILWAUKEE "Processes and procedures for an incoming inspection system" will be presented by J. E. Gottschall of Zenith Radio Corp. at the Apr. 16 meeting. Whether yours is a small or large company, this program will be of real value to you. Come one; come all.

MINNESOTA The section will hold its March meeting on the 19 at the University of Minnesota. The speaker will be Harmon Bayer, the well known quality control consultant from Detroit, Mich., whose subject will be "Selling quality control to management." With the rapid expansion of quality control techniques in this area, the subject should be of great interest to the management of these new industries.

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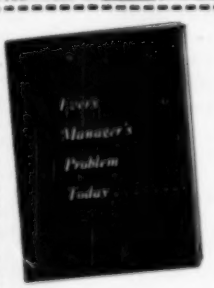

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MONTREAL The regular monthly meeting will be held on Mar. 21 with E. E. Schiesel of the Mattatuck Mfg. Co., Waterbury, Conn., delivering an address on "Engineering the product into SQC." With this topic and the speaker as well recommended as he is, there should be a good turn out.

MUNCIE J. Y. McClure, manager of quality control, Convair Division of General Dynamics Corp., Fort Worth, Texas, will speak before the section on Apr. 19. His subject will be "Quality control as a tool of management."

NORTHEASTERN INDIANA The regular meeting will be held Apr. 12, 8 pm, at the Chamber of Commerce, Fort Wayne. The educational period will feature R. N. Snyder on the moving range of two. The guest speaker will be announced at a later date.

PHILADELPHIA E. C. Harrington, Jr., Monsanto Chemical Corp., will discuss "New experimental designs in repose surface experimentation" at the Apr. 20 meeting. This topic will show how to reduce cost of experiments using the technique instead of more costly factorial designs. The meeting will be at 8 pm at Franklin Institute.

PITTSFIELD On Apr. 5 the section will hold its regular monthly dinner meeting at the Stanley Club in Pittsfield. Charles A. Reed of the Telechron Division of the General Electric Co. in Ashland, Mass., will address the group on the subject of "Visual inspection procedures."

RHODE ISLAND The section is sponsoring a big drive to beat all previous attendance records for the March meeting when Dorian Shainin, vice president of the Society, will speak on "Controlling the quality of management decisions."

Plans are in the mill for several seminars to be sponsored by the section during the months of March and April. These seminars will be free to the public.

SCRANTON -WILKES-BARRE All of our members are now looking forward to the Mar. 21 meeting to be held in Scranton. The speaker will be E. B. Ferrell of the Bell Telephone Lab, whose topic will be "New methods in the use of control charts."

SOUTHERN CONNECTICUT Apr. 11 is the night that the section is looking forward to—our own E. E. Schiesel, technical director, Mattatuck Mfg. Co., Waterbury, is to be the honored speaker. His subject will be "Statistical cost control." Mr. Schiesel is a well-known expert in statistical applications and is to present a new statistical approach to the all important control of cost. The meeting is to be held at the Stratfield Hotel, Bridgeport. Dinner will be served at 6:30 pm with the meeting getting underway at 8 pm.

SOUTH TEXAS At the Apr. 11 meeting the section will hear about some "New methods of variance analysis of production data." A. P. Woods of Armco Steel Corp., Middletown, Ohio will deliver the address and the topic is unusually timely for this section.

The training session, preceding the meeting, will be conducted by J. C. Dickson of the Humble Oil & Refining Co. Joe's subject will be "Inventory control."

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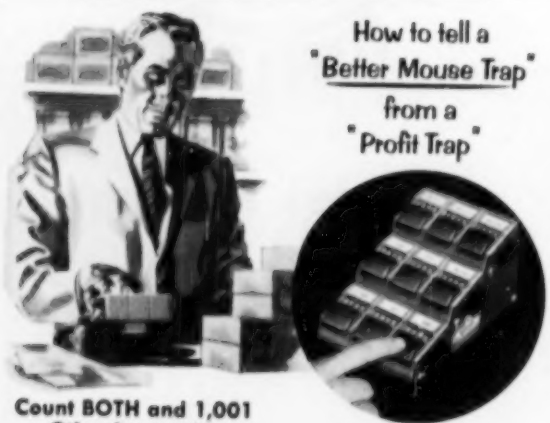

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SYRACUSE J. W. Sullivan of American Iron & Steel Institute, New York, N. Y., will address the Mar. 27 meeting. His subject will be "Applications of statistical techniques in the metallurgical field."

TOLEDO In March, the section will journey to Ottawa, Ohio to make a plant tour of the Sylvania Electric Products plant. This plant produces television tubes. The plant visit supplants the Toledo dinner meeting.

WESTERN MASSACHUSETTS On Apr. 17 at the Kimball-Sheraton Hotel in Springfield, Dorian Shainin, Rath & Strong, Boston, will be the guest speaker. Mr. Shainin, who is a vice president of the society, will speak on the subject "Use of statistics in establishing specifications."

WICHITA The Apr. 11 meeting will be high lighted by the DoAll Tool Company's program "Civilization through tooling." This program is well known throughout the industrial world and will no doubt attract quite a number of guests as well as section members.

WORCESTER The meeting of the section to be held on Apr. 12 will be ladies night. There will be a dinner followed by an entertainment program.

YOUNGSTOWN On Apr. 5 W. D. Parker, quality control engineer of the Rockbestos Corp., New Haven, Conn. will talk on "Quality control in electric wire and cable manufacture." This will be a dinner meeting and will be held in the Mural Room of the VFW in Youngstown, Ohio.

"AS YE SOW . . ."

ALLENTOWN -BETHLEHEM As the attendance figures for courses #1 and #2 indicate an ever increasing interest in quality control in the Allentown-Bethlehem area, the section is looking forward to an excellent turn out for the next course starting Apr. 2. This will be course #7, "Quality control for management personnel." This is the first time that this course has been offered in the local area.

NORTHEASTERN INDIANA Don Hensel, chairman of the annual all-day conference committee, announces excellent progress for the 10th conference to be held Thursday May 3 at the Chamber of Commerce, Fort Wayne. The program will include well-known speakers as well as a plant tour of one of Fort Wayne's larger industries. To date, we are assured that the following gentlemen will be with us: Ervin F. Taylor, North American Aviation—"Discovery sampling;" Dale Lobsinger, United Air Lines—"ASQC looks at supervision;" Harmon S. Bayer, quality control consultant of Detroit, Mich.—"Selling management on a quality control program."

QC SHORT COURSE UNIV. OF ILLINOIS MAR. 19-29 The University of Illinois announces its "Ninth short course in quality control by statistical methods" which is to be held on the Urbana campus Mar. 19-29.

The techniques presented in this course provide tools for coordinating the efforts of the design, production,

and inspection departments to produce a quality product at a reduced cost. It has been encouraging to note in each of our previous courses an increasing proportion in the attendance of men from research, design, purchasing, and production areas as well as from inspection departments.

Enrollment will be strictly limited to 50 persons. This will assure adequate housing facilities and ample opportunity for each member of the class to make personal contact with the instructional staff. Registrations will be accepted in the order received. If an applicant finds that he is unable to attend, his place may be taken by another from the same plant.

Classes will be held all-day Saturday, Mar. 24 and the last session of the course will be at noon on Thursday, Mar. 29.

Additional information may be obtained by writing to: R. K. Newton, supervisor of engineering extension; Division of University Extension; 725 South Wright St.; Champaign, Illinois.

SHORT COURSE HARVARD BUSINESS SCHOOL MAY 21-23

A three day course in the Box method of experimentation will be given at Harvard Business School May 21-23. The course is being sponsored by the Chemical Division, American Society for Quality Control. Instruction will be in charge of J. S. Hunter of the American Cyanamid Company who wrote doctoral thesis at North Carolina State College working directly under G. E. P. Box and who has had varied and profitable experience with the use of the technique both at North Carolina State College and with the American Cyanamid Co.

Enrollment in the course will be limited to 40. The fee for the course will be $100.00 including board and lodging at the Harvard Business School. For further information write Maynard S. Renner; Dewey & Almy Chemical Company; Division of W. R. Grace & Co.; 62 Whittemore Avenue; Cambridge, Mass.

GRADUATE SUMMER SESSIONS IN STATISTICS JUNE 11 - JULY 20

The University of Florida, North Carolina State College, Virginia Polytechnic Institute, and the Southern Regional Education Board are jointly sponsoring a series of cooperative summer sessions in statistics.

The third of these summer sessions will be held at North Carolina State College, June 11-July 20. A session is scheduled to be held at Virginia Polytechnic Institute in 1957 and at the University of Florida in 1958. Each summer session lasts six weeks and each course carries approximately three semester hours of graduate credit.

Courses to be offered this summer are: statistical methods I; statistical methods II (design of experiments); statistical theory I (probability and parent distribution); statistical theory II (sampling distributions and inference); sample survey designs; advanced analysis II; advanced calculus for statistics; stochastic processes; econometric methods and linear programming. Lectures on linear equations, (matrix algebra) and production functions will be given in the institute program.

Inquiries should be addressed to: Professor J. A. Rigney; Department of Experimental Statistics; North Carolina State College, Raleigh, North Carolina.

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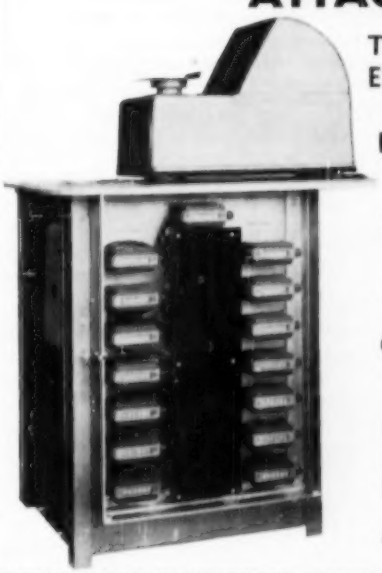

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PURDUE UNIVERSITY ADVANCED COURSE JUNE 12-22

The tenth annual advanced course in "Quality control by statistical methods" will be held June 12-22. The course is intended for those who have already had an elementary course and wish to go on to more advanced techniques.

The course has been lengthened to ten days and the notes revised. The aim is to include much more analysis of variance and some design of experiments. Other topics include significance tests and estimation, acceptance sampling by variables, sequential analysis, linear and multiple correlation, and tolerances for mating parts. This course is under the direction of Professor Irving W. Burr and will include on the instructional staff Professors Cecil C. Craig, Charles R. Hicks, Floyd A. Knowler, Edwin G. Olds, and Mason E. Wescott.

Further information may be obtained from Prof. Burr at Purdue University, Lafayette, Indiana.

SUMMER SESSIONS UNIV. OF CALIFORNIA

The 1956 summer program in the department of statistics of the University of California will consist of two sessions: June 18-July 28 and July 30-September 8. The faculty of the summer sessions will include Professor D. R. Cox of the University of North Carolina, Professor Grace E. Bates of Mount Holyoke College, and Professor David Blackwell and Mr. T. S. Ferguson of the department of statistics of the University of California.

The program includes two of the usual undergraduate courses in each session, adapted primarily to meet the needs of students transferring from other centers who would like to undertake advanced study at the University of California during the regular academic year. Also a graduate seminar will be conducted by Prof. Blackwell. This seminar will allow for individual consultation for students working toward higher degrees.

Additional information may be obtained by writing to Department of Statistics, University of California, Berkeley 4, Calif.

MEMBERSHIP CORNER

There are many who do not take advantage of the fact that it is to their interest to become Senior Members. Actually becoming a Senior Member is a recognition by the Society that one has achieved professional competence and prestige. It has been the desire of the leaders of the Society to promulgate this respect for the rank of Senior Member. In order to aid in this effort, may we ask the cooperation of all local nominating committees who work through the National Qualifications Committee.

Dr. Paul S. Olmstead, chairman of the Qualifications and Examining Committee, suggests the following procedure. On the assumption that each section has some members who have attained Senior Member grade, the Senior Members should be asked to send in nominations of members for Senior Member Grade. Then after consideration by the section examining committee, a letter might be written to each accepted nominee stating the fact that he has been nominated and if he will fill out the application, it will be processed by the local examining committee.

Dr. Fred Leone, chairman of the Cleveland section, has sent in an excellent suggestion in the form of a letter to be sent to such nominated personnel. We are indebted to Dr. Leone for suggesting this article and in general bringing up this subject.

Dear ———

You have been nominated by one of the Senior Members of the Cleveland section, ASQC, as a candidate for Senior Membership. May we request that you apply for the rank of Senior Member. Our purpose is not to urge you to become a Senior Member if you do not have the qualifications; however, if you do have the specific qualifications, it is to your best interest, and the interest of your corporation, to apply for a change to Senior Member.

According to our constitution, it is obvious that almost any person who has, or whose company has ten dollars, can become a Member of the Society. To become a Member reflects no particular prestige on the individual, his company, nor the Society. To become a Senior Member an individual must have shown an uncommon ability and must have gained a depth of maturity in his field. The ordinary man has no choice—he must remain a Member. According to our Constitution, the extraordinary man who has shown qualification for Senior Membership is one who, for example, has planned and taken responsibility for important engineering for inspection work in the quality control field for a period of five years. Half of this period can be in work of similar responsibility in an allied field. The Senior Member might be one who directs the efforts of the ordinary Member.

Everyone cannot become a Senior Member. Those comparative few who can should certainly do so. Senior Membership signifies a professional status and professional accomplishment as compared with the status of an ordinary Member of any organization. When an individual is successful in a chosen field he should not hide his accomplishments and let others take the credit. It is not a matter of boasting to take credit for accomplishment but, rather, a just recognition. Senior Membership in a technical society of the status of the American Society for Quality Control immediately indicates the caliber of the individual and, undoubtedly, points to the fact that he is recognized by his peers as a success in his profession.

It is of definite value to an individual's morale to accept a standing as Senior Member since this honor is bestowed only upon a comparative few. It is definitely of importance to his corporation that a man with the caliber to be a Senior Member should make this evident. Not only in relationships in the company, but also with other companies, is it of value to know that particular individuals have, through their abilities, been recognized as men of high caliber in their profession. Almost all major industrial organizations in the United States recognize and take heed of the fact that a man has a status of a Senior Member instead of having simply a membership.

In the community as a whole, the fact that one is a Member of a technical society implies little. Professional prestige, however, is attached to the Senior Member. One excellent way to show that we do have the ability and responsibility in carrying out the many scientific efforts of our day is by taking advantage of the fact that we have the qualifications of a Senior Member, and becoming one.

The cost differential between a Membership and a Senior Membership is less than the cost of a good dinner, so this is no factor whatsoever. The main fact is—are you but a routine Member from a qualification

standpoint, or are you really an able, professional man in the quality control field? If you really qualify as a Senior Member, become one.

An application form for transfer to the grade of Senior Member and an envelope, addressed to Mr. Paul Kuckuck, our secretary, are enclosed. Simply fill out the application form and send it with a check for $2.00 to Paul, and he will take it from there.

Sincerely yours

Fred C. Leone, Chairman
Cleveland Section
American Society for Quality Control

SIGNIFICANT DIFFERENCES

Bernard Sussman, a member of the Binghamton section, has recently transferred to a new position as manager of quality control at the General Electric Co.'s plant in Waynesboro, Va.

Upon his retirement from American Cast Iron Pipe Co. after a lifetime of valuable service, Dr. James T. McKenzie, a member of the Birmingham section, known nationally as "Mr. Cast Iron" for his many contributions in pipe manufacture, will become associated with the Southern Research Institute. In his new capacity he will continue valuable investigations into problems, the solution of which will be aided by his long experience.

At a recent meeting of the AIME in Chicago, Robert Franks of the Inland Steel Co. and a member of the Calumet sub-group of the Chicago section, addressed their membership on "Statistical quality control in the coke plant."

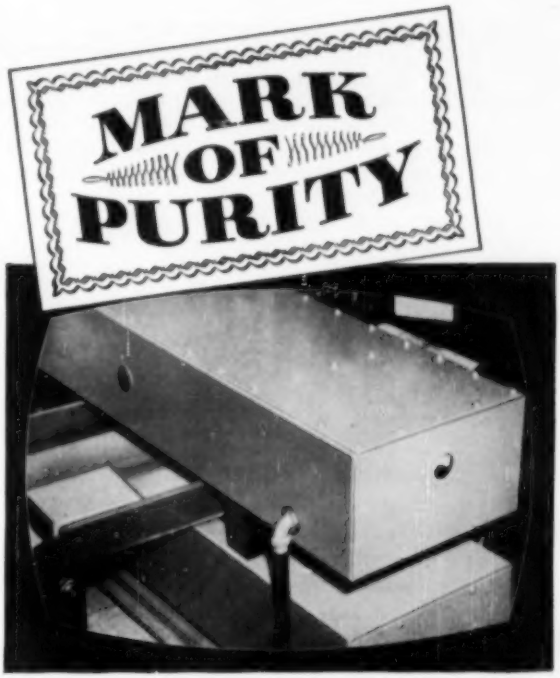
Gordon A. Olson, past chairman of the Columbus section, has been promoted to assistant supervisor of quality standards of Ternstedt's Columbus plant.

Ernest Beck, formerly assistant chief inspector of the Borg-Warner Corp., Wooster, Ohio, has accepted the position of quality control engineer with the F. E. Meyers & Brothers Pump Co., Ashland, Ohio. Mr. Beck is a member of the Columbus section.

E. B. Godsey, of the Corning Glass Works, Corning, N. Y., has been promoted from quality control engineer in the technical products division to the staff quality control department. Mr. Godsey, a senior member of the Corning-Elmira section, will be in charge of incoming inspection of purchased materials.

Ye Olde Yearbook—The Milwaukee section's Yearbook committee, under the capable leadership of Irv Schoeninger of Globe-Union, Inc., has completed its chore. ASQC's finest Yearbook has been sent on its way to the 3350 members who requested it. We owe the ten man committee a vote of thanks for giving a helping hand with its publication. After five months of sorting, proof reading, stuffing and stamping, this committee has much to show for its efforts: these half blind, sticky tongued, fellow members are the proud possessors of a bumper crop of hangnails. It's great boys; thanks!

Top quality for the new national ASQC office—by this we mean, Jean Truettner, the "our gal Friday" for the A. O. Smith Corp. quality control staff, has joined the



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national office staff. The staff at A. O. Smith had a farewell luncheon for Jeanie on Jan. 28 at which time she was presented a "good luck" desk clock to adorn her new desk. Jean has always given generously of her time and talents in Milwaukee section activities and is currently one of its directors. All of us in the section wish her the best of luck and we are expecting great things of her in the new position.

The Philadelphia section is active in QC work. Attesting to this, our Leo Jacobson and C. Ryerson presented papers at the 2nd Annual Symposium on reliability of quality control. C. Ryerson was selected program chairman and Dick Jacobs publicity chairman for the 3rd Symposium to be held in Washington, D. C. Jan. 14-15, 1957.

The response to the Philadelphia section's wage survey announcement in the January issue of IQC was overwhelming. Another 1000 copies of the survey have had to be printed. Those still wanting a copy may contact the author, R. M. Jacobs, Building 13-2, RCA, Camden, N. J.

George Soyka, former publicity chairman and active member of the Pittsfield section, has resigned his position as technical director of Byron Weston Co., Dalton, Mass., to accept a new post with John W. Bolton & Sons, Inc., Lawrence, Mass.

Wm. H. Von Meyer, St. Louis section secretary, has been promoted to director of research for Barry-Wehmiller Machinery Co. Our congratulations to you Bill on this new assignment.

The Southern Connecticut section has become a member of the Engineering and Technical Society Joint Committee (Fairfield County Area). The objective of this joint committee is to promote a closer society interrelationship, provide a forum for representatives of member organizations, and to consider matters of mutual interest. All societies in the Fairfield County area organized for furthering the interests of engineering or technical development and the sciences are eligible to membership on the joint committee. The representatives from the section are Edward W. Demers, quality control engineer, Metalix Mfg. Co., Norwalk, and William Adams, supervisor of quality control, Byrant Electric Co., Bridgeport.

Members interested in textile applications of statistical methods may not all be aware of the series of articles on the statistical and management aspects of quality control which have appeared over the past two years in 15 issues of *Modern Textiles Magazine*. These are now available in reprint form in two separate volumes, "Quality control through statistical methods" and "Modern mill controls," direct from the magazine, 303 Fifth Avenue, New York 16, N. Y. An additional series of articles is appearing during 1956, in response to reader request, covering the details of procedures as applicable to each individual processing department, in cotton, woolen and worsted, and synthetic spinning and weaving. The author, Norbert L. Enrick, has assisted in the installation of statistical quality controls in over 60 mills in the last eight years and is research statistician for the Institute of Textile Technology.

Winston Dalleck, senior member of the Chicago section, has been promoted to the position of superintendent of quality control and applied statistics in the recently created operations research and applied science division at the Chicago headquarters of United Air Lines.

What's New?

ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL.

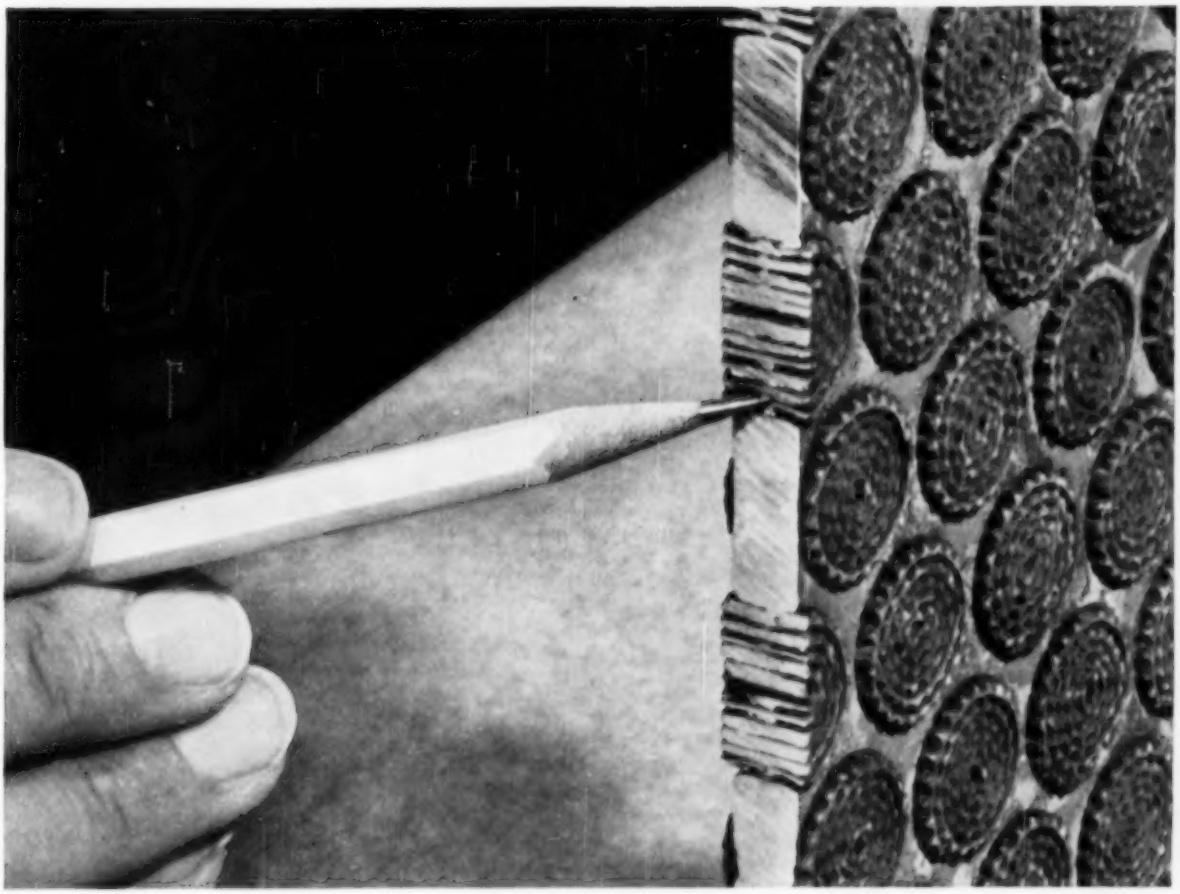
KP National Sales, 1036 Terrace Street, Muskegon, Mich., are marketing the Precision Quick-Check Angle Finder, a new idea in a protractor for fast checking of single point tools, both carbide and high speed. The instrument will check angle of the cutting edge as well as top rake and side clearance angles. It is self-aligning and will accurately check and project any angle as fast as the tool can be moved from one angle to another. No setting is required between tools or for different size tools thus allowing the use of the instrument by more than one operator without interference. Tools up to 2¼ inches high can be checked for cutting angle while tools up to 1¾ inches high can be checked for clearance angle. Top rakes may be checked on any angle from the cutting edge. All checking is done using only one side of the tool shank to eliminate accumulative error. Right or left hand tools may be checked equally well. All surfaces subject to constant wear are carbide tipped.

★ ★ ★

The Denominator Co., Inc., 261 Broadway, New York 7, N. Y., announce the availability of the DENOMINATOR unit for the rapid processing of inspection data. The DENOMINATOR unit makes possible a running tally of inspection results at final inspection or at a group of in-process inspection stations. Without waiting for periodic test reports, supervisors can compare readings on the DENOMINATOR and make production adjust-

EXIDE-MANCHEX BATTERIES

Emergency power source for generating and substations



Spiral buttons act like shelves for oxide—prolong battery life

SWITCHGEAR BATTERY. Exide-Manchex Batteries are available in a wide range of capacities from 40 to 960 ampere hours, with improved high rate discharge characteristics. Compact construction saves space and weight. Flat cover easy to clean. Write for Bulletin No. 4852.

In ordinary batteries, the active material clings to the vertical surfaces of the positive plate—forever fighting the forces of gravity and turbulence. Let it loosen its grip and down it comes. And there goes battery life.

Not so with Exide-Manchex Batteries. Active material is built up between the spiral layers of these unique lead buttons that act like tiny shelves. There it rests, supported against gravity and electrolyte turbulence. And there it stays for years and years and years.

This simple design principle is one of the several tangible reasons for the long, useful life of Exide-Manchex Batteries. Used in a wide variety of floating service applications, these batteries have earned a reputation for long, dependable service unsurpassed in the entire world. And this method of construction is available only in Exide-Manchex Batteries.

When you order batteries for applications where you need dependable performance and long, useful life, or when you buy equipment using this kind of battery, be sure to specify Exide-Manchex Batteries. Exide Industrial Division, The Electric Storage Battery Company, Philadelphia 2, Pennsylvania.

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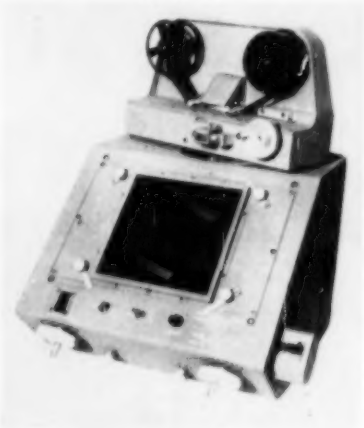
ments as necessary. With a totalizer unit easy computation of variances in terms of percentages is possible. In other applications, summary of inspection results as shown on large numbers of inspection reports, can be made quickly. The DENOMINATOR is especially useful in tallying visual inspection results. Number and nature of slight defects or flaws in finished products is an important element in grading. While there may be no complete "rejects," there is often a final inspection to determine degree of perfection or down-grading of inferior products. DENOMINATOR units provide the tally of defects necessary for proper grading. A few of the products which lend themselves to this type of inspection are packaged foods, flowers and citrus fruits, textiles, TV tubes, hosiery, lumber, automobiles, fiberglass, etc.

★ ★ ★



A new 35mm Motion Analyzer has been introduced by **Vanguard Instrument Corp.**, 184 Casper St., Valley Stream, N. Y. The unit is particularly suited to research and development activities using 35mm cameras. The projector is used to measure linear motion versus time interval. For angular measurements, a circular rotatable screen with a graduated circle is supplied as optional equipment. No special skill is required to operate the M-35, nor is a darkroom required. Velocities, accelerations, deflections and stresses can be determined from filmed image at the engineer's desk. The M-35 produces an image 0.750 x 0.980 inches at the standard 5X magnification, and accommodates up to 400 feet of film. Adaptable to either high or low speed motion picture analysis, the Vanguard M-35 also features a frame counter which adds or subtracts, frame registration pins to position each frame, film transport which operates forward or reverse by power or manually. The projec-

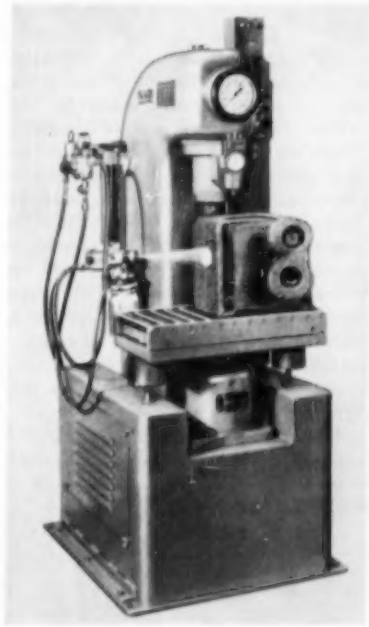
tion head may be rotated 180 degrees to align angular motions on film with either of two cross-hairs. Cross-hair positions may be read to an accuracy of 0.001 inches by dial adjustment.

★ ★ ★

A new single purpose impact tester designed to meet the specific needs of those interested in Charpy Impact Tests has been introduced by the **Tinius Olsen Testing Machine Co.**, 6012 Easton Road, Willow Grove, Pa. The 120 ft.-lb. capacity Charpy Impact machine provides high testing accuracy and meets all government requirements for normal and cold temperature testing of metals, plastics and various other materials. The machine minimizes deflections and eliminates variables by transmitting the impact action directly to the heavy base. The vise, an integral part of the base, affords maximum clearance for broken specimens while the striking bit permits making Charpy Impact tests with a minimum number of parts. In operation, a specimen is centered in the vise at the base of the tester. The operator, by moving a latch-lever, releases the one piece hammer and pendulum which swings down, strikes specimen then follows on through to a height dependent upon the amount of energy absorbed in breaking the specimen. An indicator remains at point of absorbed energy. On the return swing, the hammer is caught, lifted into the latch in position for the next test while all necessary adjustments are made from the front cover and dial of the machine.

★ ★ ★

Steel City Testing Machines, Inc., 8817 Lyndon Avenue, Detroit 38, Mich., have designed a new Brinell Hardness Tester with a paint spray attachment. The attachment synchronizes with the testing cycle of the machine so that relative hardness of parts is automatically indicated by a spot of paint. Sorting of pieces is in effect done by the machine rather than by the operator, resulting in less fatigue and fewer errors. The tester is designed to fit right into a roller conveyor supplied by the customer. Castings from the foundry are rough ground top and bottom to remove most of the scale and then are rolled into place on the roller section of the Brinell tester. The operator locates the part by means of a stop located at the rear of the rollers. He then manually depresses the cycle start button to the right of the load gauge, starting the hydraulic cycle of the machine. As the Brinell ball descends toward the casting, the roller section drops down, leaving the casting firmly seated on three hardened anvils, one of which is immediately below the penetrator. The Brinell impression is made and, if the part is acceptable from the standpoint of hardness, a spot of paint is automatically sprayed onto the casting. After a pre-determined



interval, the load is released, the ball penetrator retracts and the rollers lift up so that the operator can roll the casting down the conveyor to the next operation. At the end of the conveyor, castings are sorted. Those that are not sprayed are sent to the heat treating department while those that are "OK" are sent on for machining. Brinell limits on the machine are completely adjustable in accordance with the user's requirements.

★ ★ ★

Sperry

ultrasonic inspection news

40-Foot Aluminum Extrusions Inspected Under Water

How to inspect 40-foot, 1850-lb. aluminum extrusions for internal defects prior to machining into helicopter blades?—Piasecki Helicopter Corp., Morton, Pa., required an immediate answer to this problem.

The solution was provided by Sperry Products' Commercial Testing Service. At Sperry's Danbury laboratory personnel and equipment were available, including a 100-foot tank which would permit ultrasonic immersion inspection of the huge extrusions.

Actual inspection was done with a Sperry UW Reflectoscope and a PH Positioner. Mounted on an electric car which also carried the operator, this unit was capable of testing at speeds ranging from 2 feet to 32 feet per minute.

To best meet your individual inspection requirements, consult Sperry Products Commercial Testing Service. Return coupon for full information.

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Danbury, Connecticut

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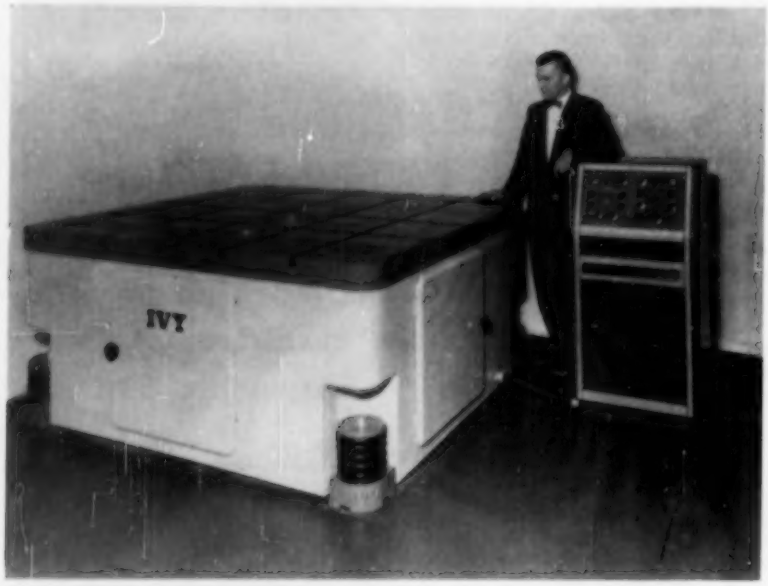

The Ivy Co., Norwalk, Conn., has introduced a new fatigue testing machine with total force capacity of 12,000 lbs. It is a constant force machine designed for Multi-Range fatigue testing. This is the latest of a standard line of similar machines with capacities ranging from 200 lbs. to 120,000 lbs. The Multi-Range feature provides two test stations—one for high force and the other for high amplitude operation. The dual range feature is achieved by using a torque bar instead of coiled springs. The torque bar not only provides for high amplitude but also permits use of the machine with heavy test pieces and fixtures. In addition, the torque bar is immune to errors normally attributed to temperature changes. At the high force station the maximum load is 12,000 lbs. and the total available amplitude is ± ⅜ inches. The high amplitude station provides for ± ¾ inches amplitude and a maximum force of 6,000 lbs. Settings for both static and dynamic forces are calibrated directly in pounds. Static force is maintained constant by the IVY-PIC electronic controller. The table surface is 71 by 79 inches and is 37¼ inches high with five T-slots in each direction. The entire unit is seismically mounted.

★ ★ ★

Davidson Mfg. Co., West Covina, Calif., have recently placed on the market an auto-collimator which is unaffected by movement or mounting. The new Davidson instrument may be shifted and moved at will and needs no fixed base or position to secure repeat and accurate readings of the same or different surfaces. It is designed for quick and continuous operation and requires none of the control of temperature and movement usually necessary to auto-collimator accurate measurements. The Model D-600 Comparison Auto-collimator may be used as a separate testing instrument or may be built into another and more complex test fixture wherein flatness or adjustment of optical elements may be instantly measured against preset optical reference flats. Several auto-collimators may thus be employed together to check an optical assembly with a number of flat surfaces to be measured almost simultaneously. Within the Davidson instrument are two optical tipping-plates set immediately behind the objective lens. One of these plates is fixed in position, the other is linked to a calibrated micrometer dial accurate to $\frac{1}{10}$th second of arc. By means of these two optical plates or windows the differences in parallelism of two surfaces may be read. Monochromatic light passing through a scribed reticle in the auto-collimator is projected against a known flat surface, such as an optical flat, and against another ground and polished surface under test. The auto-collimator is shifted around until the image of the returning beams from the optical flat is seen through the stationary plate or window. The surface being tested is then placed in such relationship to the optical flat that the returning beam from that surface is seen through the movable window or plate in the auto-collimator. The

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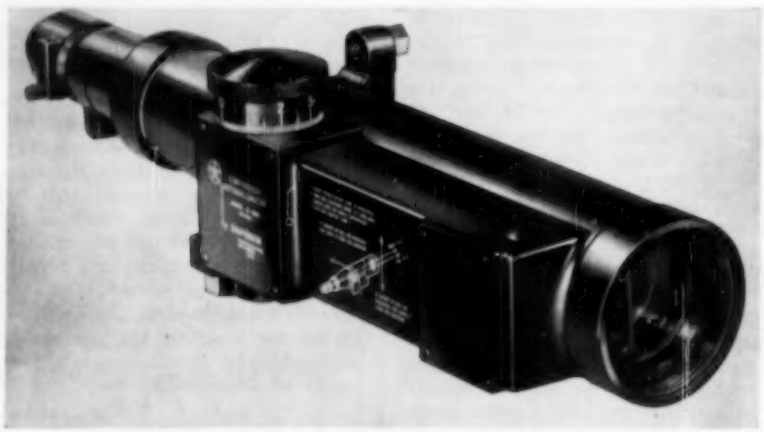

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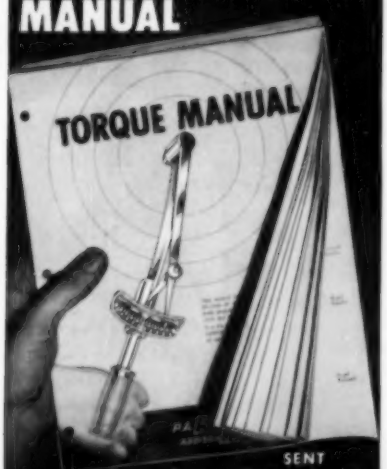

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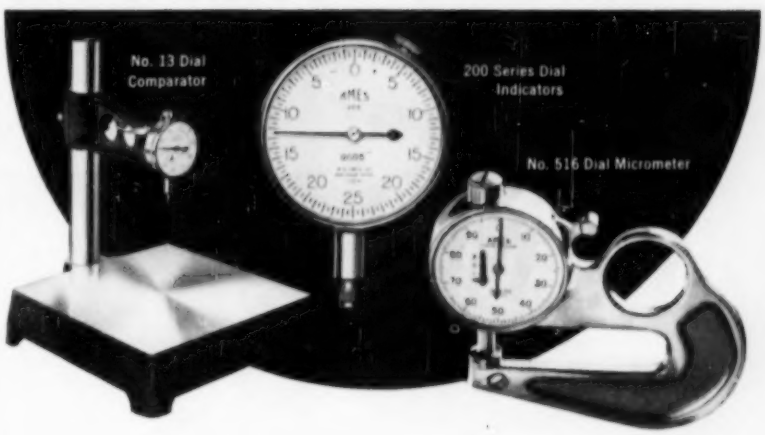

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result will be two separate images of the twin reticle lines as seen in the eyepiece field-of-view. By manipulation of the micrometer dial, the two pairs of reticle lines are brought into accurate interspersion and the difference in surface flatness between the test optical flat and the work under inspection may then be easily read on external gages on the auto-collimator.

★ ★ ★

New Literature

Associated Research, Inc., 3758 West Belmont Ave., Chicago 18, Ill., have made available Bulletin 5B describing their revised line of high voltage a-c test sets. Included as standard are the series 500 Mobile type for field or plant use available in 3 KVA capacity and voltages up to 30 KV, series 570 semi-portable type for plant or laboratory also available up to 30 KV, and custom units up to 150 KV and 25 KVA.

Metal & Thermit Corp., 100 East 42nd Street, New York 17, N. Y., has published Bulletin P-196 describing the new Kel-Ray Projectors for industrial radiography with gamma rays. Manufactured by the M. W. Kellogg Co. and sold exclusively by Metal & Thermit, the projectors are available in three sizes and offer a choice of radioactive isotopes of different intensity. The bulletin explains how the portability, safety, versatility and economy of the new gamma ray equipment expands the range of applications in which radiography may be used as a practical, economical tool for non-destructive testing.

Edmund Scientific Corp., Barrington 7, N. J., have published a new 64-page catalog covering more than 1,000 optical items. Included are many quality control tools, such as measuring magnifiers, microscopes, pocket comparators, and other optical instruments. Also included are telescopes and accessories, lenses, prisms, wedgers, hand spectroscopes, reticles, mirrors, astronomical telescopes, binoculars, photographic items.

The Johnson Gage Co., 534 Cottage Grove Road, Bloomfield, Conn., have published a paper entitled "The Correlation between Screw Thread Standards and Gaging Systems." This paper was delivered to an Instrumentation Clinic of the Hartford Chapter of the American Society for Quality Control in November 1955 by Mr. Clinton V. Johnson of the Johnson Gage Co. This paper

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Now even the smallest shop can afford a dependable and versatile Brinell Hardness Tester. Priced exceptionally low, Model L is a motorized hydraulic machine with which even an inexperienced operator can make tests in strict conformance to A.S.T.M. Standards.
Engineered by Steel City, leader in the field since 1914, the new tester is designed for years of maintenance-free operation. The ¾" stroke permits successive tests without anvil readjustment. Load is applied by finger-tip pressure on operating handle.
Write for full particulars today and name of nearest sales representative—conveniently located in your area.
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Vert. opening—9"
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Manufacturers of machines for testing physical properties of metals, including:
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remain perfectly round through full range of adjustment and retain setting while in use.
2½ to 12 times longer life—over 50% less weight than conventional gages.
Also Thread Plug Gages, Cylindrical Plug and Ring Gages, and Master Setting Discs
Consult your classified phone directory for nearest of 38 DoALL Service-Stores stocking gages, cutting tools, supplies.
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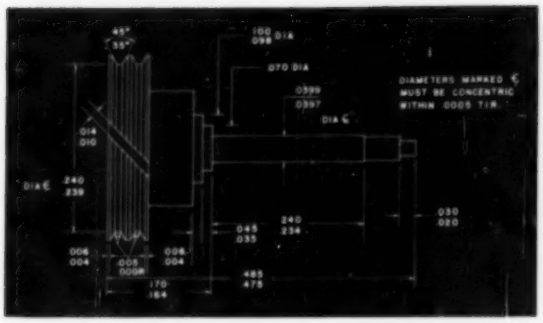
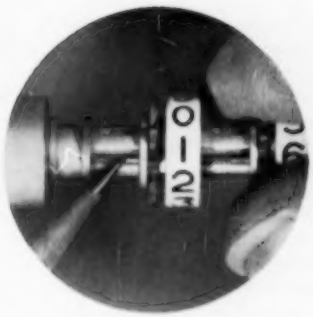
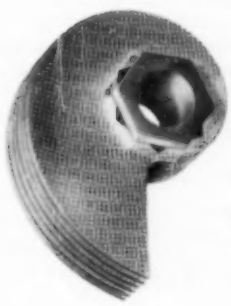


Inspection of incoming precision shafts took 10 to 15 minutes each by mechanical gaging—involved concentricity, diameters, shoulder locations, and other tough-to-measure dimensions to tolerances of .0002". Doing the work on a Kodak Contour Projector cut time to 2 to 3 minutes per shaft.



The problem was to check many small calculating machine parts averaging about 13 critical dimensions for each with shapes mostly complex. With carefully engineered mechanical gages, inspection time averaged 50 seconds each. Optical gaging on a Kodak Contour Projector brought the average down to 12 seconds.



Spacing the parallelism of a special tuning condenser for electronic test equipment had to be held to very close tolerances. "Use of the Kodak Contour Projector," the company reports, "permits economical measurements of parallelism to an accuracy impossible to obtain by other methods."

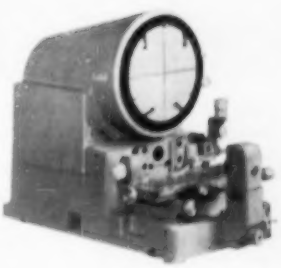
On a flexible rubber-like part, rejects ran as high as 30%. By using a Kodak Contour Projector to measure the parts and then plotting results by statistical quality control methods, production changes were made that resulted in rejects dropping from 30% to less than ¼ of 1%. Optical gaging eliminated distortion of the part while gaging, and proved 4 to 5 times faster than usual methods.

One instrument inspects these varied parts

Here is another economy optical gaging can provide: switching from one part to a second part requires only a change of chart and fixture. You still use the same basic instrument. And with a Kodak Contour Projector, the variety of parts you can check is almost without limit. Here's why:

1. *Capacity*—Screen size on an optical comparator does not restrict the size of parts you can handle, for multiple-position fixtures allow the handling of parts larger than the screen itself. What's important is the staging area—and Kodak's unique relay lens provides uniform ample clearance regardless of magnification. The distortion-free image lets you measure anywhere on the viewing screen. The choice of lenses, of horizontal or vertical projection, and of surface or shadow illumination gives you the greatest possible flexibility.
2. *Ease of operation*—Kodak Contour Projectors are designed for maximum speed and minimum operator training. The bright screen image reduces fatigue, lets you use the instrument in normal room light. Images are erect and unreversed at all magnifications. Finger-tip controls are within convenient reach of the operator.
3. *Optical stability*—The adjustment-free optical elements on Kodak Contour Projectors eliminate the need for operator adjustments. Rigidly mounted lenses and mirrors maintain alignment and position. Rugged construction withstands rough and heavy use.

Whether you are now using optical gaging or just considering it, you should have a copy of the booklet, "Optical Gaging with Kodak Contour Projectors." It gives complete details on Kodak optical gaging equipment and how it can work for you. Write to *Special Products Sales Division.*



To see the latest developments in optical gaging, visit Booth 917, ASTE Show, March 19-24, Chicago.

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the KODAK CONTOUR PROJECTOR

Kodak
TRADE-MARK

traces the development of screw-thread standards and their relationship to the various thread gaging systems now in use.

Morehouse Machine Co., 233 West Market St., York, Pennsylvania, have published a new catalog covering their line of certified proving rings. A proving ring is a circle of elastic steel, equipped with a micrometer screw and a highly sensitive vibrating steel reed. When the ring is given either a tensile or a compression load, its very minute deflections may be accurately measured. Certified proving rings meet all Federal and ASTM specifications for calibrating materials-testing machines. In this bulletin various applications are pictured and details are given of the ring dynamometer and weighing and calibration system developed by the manufacturer to extend the field of proving-ring usefulness.

"Cenco News Chats" Number 81, published by Central Scientific Co., 1700 Irving Park Road, Chicago, Ill., contains descriptions and photos of new and redesigned instruments and apparatus for laboratory use including a coulometric mercaptan titrator, vapor equivalent apparatus, vacuum pump, laboratory Geiger counter, safety tube inserter and many others. Also included in the booklet are scientific features including an article on Dr. Saul Dushman, late assistant director of General Electric's research laboratory and a pioneer in vacuum technique.

Federal Products Corp., 1144 Eddy Street, Providence 1, R. I., now has ready for distribution two new and improved catalogs describing the extensive line of Dial Indicators and Dial Indicator Gages available today. This is the first time that separate catalogs for Dial Indicators and Dial Gages have been published by the company. The separation was made in order to simplify selection of the proper gage from the ever increasing number of styles and types of dial gages being used throughout industry.

CORRECTION NOTICE

A typographical error occurred on page 11 of Henry I. Matosoff's article "Corrective Action in a Quality Control Program," which appeared in our January issue. The first paragraph should have read

"•The data on the QDR is checked with the QDR initiator; corrections and additions if necessary are made." Our apologies.

OUR COVER

The Shakespearean quotation used on this month's cover was suggested by Mr. J. O'Callaghan, British American Oil Company, Ltd., Operations Control Department, Toronto, Ontario.

REPORT OF NOMINATING COMMITTEE

Following are the candidates recommended by the Nominating Committee for election to the offices indicated.

For President:
Dale L. Lobsinger
United Airlines, Inc.
Denver, Colorado

For Vice Presidents:
Leon Bass
General Electric Company
Cincinnati, Ohio
C. E. Fisher
Bell Telephone Laboratories, Inc.
New York, New York
Ellis R. Ott
Rutgers University
New Brunswick, New Jersey
Ervin E. Schiesel
Mattatuck Manufacturing Co.
Waterbury, Connecticut

For Executive Secretary:
Leslie S. Eichelberger
A. O. Smith Corporation
Milwaukee, Wisconsin

For Treasurer:
J. Y. McClure
Convair
Fort Worth, Texas

Each of the above named candidates has indicated his willingness to serve if elected to the office for which he has been nominated.

POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

Position wanted with company having an effective statistical quality control department. Eight years experience in the field which includes design and analysis of experiments and statistical quality control. Experienced in supervising professional, semi-professional, and payroll personnel. Graduate work in mathematics and statistics. Please reply to Box 12J1 at the above address.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

QUALITY CONTROL MANAGER

Midwest manufacturer of electromechanical devices requires a manager who has had experience as chief inspector or assistant chief inspector. Must have mechanical and electrical background. Excellent opportunity to advance in very progressive company. Quality control manager will also direct an inspection force of 75 people. Large portion of units go into missiles, aircraft, fire control systems and radar. State educational background, experience and salary requirements and resume to Box 12W1 at the above address.

QUALITY CONTROL MANAGER
(Greater New York Area)

A well established, nationally known manufacturer of carbon papers, inked ribbons, etc., has an exceptional career opportunity for a man acquainted with PAPER CONTROLS as well as CONTROLS ASSOCIATED WITH A COATING OPERATION USING HOT-METAL MATERIALS. THE RIGHT MAN will be qualified to supervise a group responsible for statistical control, plant inspection, establishment of raw material and product specifications—as well as testing procedures. Also maintaining quality levels.

REQUIRES: Technical education (preferably in chemistry). Preferred age 28 to 40 years. Please submit resume in confidence.

WESTON RICHARDSON AND ASSOCIATES
MANAGEMENT CONSULTANTS
6 East 45th Street
New York 17, N. Y.

DETONATOR MANUFACTURER in Eastern Pennsylvania has staff opening for a quality control engineer. Bachelor degree or equivalent in electrical, chemical, mechanical, or industrial engineering plus three years' experience and training in statistical quality control and statistical techniques, or a Bachelor degree in mathematics with a physics or chemistry minor plus three years' experience and training in statistical quality control and statistical techniques. Forward resumé with salary requirements to Production Control Manager, Explosives Department, Atlas Powder Company, Wilmington, Delaware.

QUALITY CONTROL ENGINEER

To assume administrative position in Quality Control organization currently responsible for receiving, machining, sub-assembly and assembly operations. Some knowledge of basic Quality Control statistical techniques required. Must be capable of helping in the formulation and administration of all phases of quality control policies, procedures and management. Applicants should send resume of education, experience and salary requirement.

The United States Time Corp.
Post Office Box 2740
Little Rock, Ark.

QUALITY CONTROL ENGINEER

Sandia Corporation, an AEC prime contractor working on the design and development of nuclear weapons, now has several openings for experienced quality control engineers. Members of the laboratory staff in the quality control group have a number of interesting and challenging responsibilities, including: 1. The analysis of data in quality summaries and control charts. 2. The provision and interpretation of sampling plans. 3. Conducting training programs in quality control for inspection personnel. 4. The evaluation of inspection effectiveness, and, 5. The evaluation of the quality performance of various suppliers. Located in metropolitan Albuquerque, Sandia couples the benefits of these rewarding positions with the high, dry, and healthful climate of the mountainous Southwest. Applicants must have a degree in mathematics or in mechanical or electrical engineering; a minimum of 3 years experience is desired.

Please send your resume to:

Staff Employment Section 564
SANDIA CORPORATION
Albuquerque, New Mexico

Reliability Engineering

MARTIN Analytical position for individual with a minimum of five years in environmental or qualification testing. Electronics, physics or electrical engineering degree. Administrative and managerial potential.

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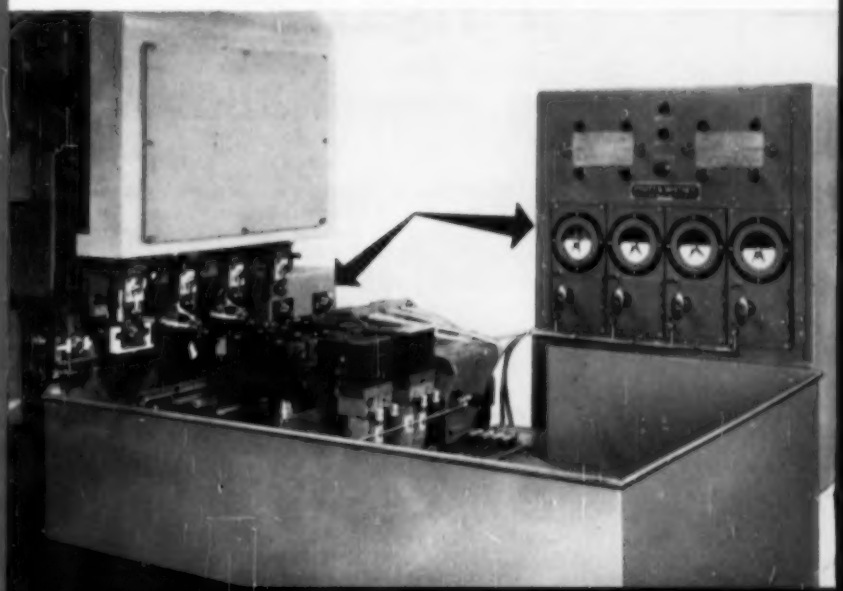
HERE'S HOW
THE NEW BRITAIN MACHINE COMPANY
PUTS P&W AUTOMATION GAGING TO WORK



Applied to a New Britain-Gridley Automatic Dual Boring Machine, Pratt & Whitney AUTOMATION GAGING provides in-process gaging plus "feed-back" control for automatic tool resetting.

The results: *Far greater accuracy* with a tolerance of .0003" constantly maintained in regular production. *Very high output* – machining internal and external diameters and facing at a rate of 120 pieces per hour – because down time for checking parts and adjusting the machine is eliminated. *Lower production costs* – thanks to *fully* automatic operation and fewer rejects.

You've *heard* about Automation . . . THIS IS IT . . . proved, practical and ready to go to work for you right now. So write West Hartford, outlining your production problems, and let P&W Automation Gaging Engineers help you produce more accurately, more profitably . . . automatically.

PRATT & WHITNEY COMPANY
INCORPORATED
26 Charter Oak Boulevard, West Hartford 1, Connecticut

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*OFFICE ONLY

Quality Control Engineers

for positions in SOUTHERN CALIFORNIA

HUGHES, one of the nation's leaders in the development and manufacture of advanced electronics systems and components, has new openings in the Quality Engineering Department for Engineers experienced in the following fields:

STAFF ENGINEER

To correlate factory test with results in the field, analyze complete systems in terms of component quality requirements, develop and install advanced techniques for manufacturing and suppliers' operation.

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To evaluate present inspection techniques employed in such areas as Machine Shop, Mechanical and Electrical Assembly, Receiving Inspection and the Processing Departments. Must evaluate Production Planning, operation call-outs, and assign classification of defects to each operation.

TEST FACILITIES ENGINEER

To analyze, plan and review design of quality control test equipment and test methods to comply with advanced electronic and electromechanical specifications.

These positions require an M. E. or E. E. degree with a mathematics or engineering background, and actual shop experience in the application of statistical techniques to electronics manufacturing operations.

The ability to design and follow through on statistical quality control procedures is essential.

These are responsible positions which will provide you with opportunity for professional advancement.

For further details, you are invited to send your resume direct to MR. HOWARD A. GRIFFIN *at the address below.*

Hughes

11940 W. Jefferson Blvd.

Culver City, Los Angeles County, California

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Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

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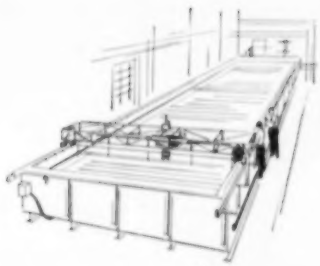

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Curtiss-Wright Non-Destructive Test Equipment uses "ultrasound"—high frequency mechanical vibrations—for precision production-quantity inspection of forgings, rolled plate, welded tubing, extrusions and other metal products.

A "search crystal" immersed in water is electrically excited to produce several million cycles per second. The resultant vibration passed through the liquid readily penetrates metals . . . then bounces back from the front or rear surface of, or from interior flaws in, the material. The flaws are translated into "pips"—visible readings on the cathode ray tube of the Curtiss-Wright Immerscope. The Immerscope, most important unit in the Curtiss-Wright test system, has a built-in alarm system which provides positive warning when flaws of a predetermined size are present. Scanning equipment for cross-sectional views, and a Flaw Recorder for keeping a permanent record of all data, are important accessories for complete automation in quality control.

Curtiss-Wright Ultrasonic Test Systems, and other important developments in ultrasonics, are serving many of the nation's leading industries. Complete information and engineering assistance available on request.

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Curtiss-Wright has permanent career positions open for specialists in advanced engines and propellers, metallurgy, electronics, nucleonics, ultrasonics, plastics and chemistry. New 85-square-mile Research and Development Center at Quehanna, Pennsylvania and expanded divisional engineering programs are creating opportunities for more engineers, technicians and scientists in both aviation and diversified industrial projects. . . . Write to: Engineering Placement Department, Curtiss-Wright Corporation, Wood-Ridge, New Jersey.

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At the ASTE Show (Booth 496)

Federal introduces for the first time, at the Show, these instruments which offer new advantages in gaging. We suggest you investigate them for use in your plant.

NEW

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Illustrated with tail stock backed off.

A long range indicating device for accurately determining tool position with relation to a predetermined reference. It indicates to the operator (within .0025") when the cutting tool has covered the required distance on the workpiece. Provides much-needed machine control for repeat operations, when roughing down to size, particularly where the tool travel is long. Can be readily located on any machine tool carriage regardless of table travel. It eliminates scrap, increases machine productivity and maintains dimensional quality.

We will be glad to tell you more. Write today.

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